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THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. III

ROCKS OCCURRING IN DIKES

THE rocks described in the preceding part of this article are cut by numerous dikes of various kinds, ranging from very acid aplites to basic diabases. The last are, as is usual along the Atlantic border, the most numerous; aplites and acid granite-porphyries come next, and finally there is a smaller number of rare and interesting types of alkali-rich dike rocks. These have not yet been fully investigated, but, as the rather large number of specimens in my possession represent apparently the main types, a description of them will give at least an approximate idea of the intrusive rocks of Essex county.

GRANITIC DIKES

Aplite.— Dikes of this rock are confined almost exclusively to the granite areas, at least as far as my observations permit me to judge. They are usually very narrow, only a few inches in thickness, and contact phenomena are not very conspicuous.

Megascopically they are dense and fine-grained, of various shades of light gray, and often showing a few small biotites. In thin section they show no very remarkable peculiarities, being a holocrystalline mass of small anhedra of quartz and alkali-feldspar, the latter usually microperthitic. Micrographic inter-

growths of feldspar and quartz are rather common. Colored components are rare, those most often met with being olive-green hornblende and brown biotite, while colorless diopside is less frequent. A few specimens carry titanite and magnetite, while apatite is seldom seen. These aplites are occasionally coarser-grained, and become microgranites, when they resemble closely the granites proper, except that the crystallization is on a smaller scale, and colored minerals are rare.

The most interesting aplitic dike found is one cutting a granite exposure near Bass Rocks, Gloucester. It is the same mass as that mentioned previously with enclosures of orbicular syenite and diorite, and the aplite cuts granite and enclosures impartially. The dike is only 6–7 cm wide, and is notable on account of being compound in an anomalous way. The borders, about 2 cm on each side, are of fine-grained white microgranite speckled with small, black biotite and hornblende flakes. This shows under the microscope the usual microgranitic structure and characters. Extending down the center is a band, about 2 cm in width, of a dense, almost aphanitic light gray aplite, which shows under a lens only very minute black specks. This in thin section is a very finely granular aggregate of round quartz and alkali-feldspar anhedra, with here and there small shreds of green hornblende and pale brown biotite.

The junction between the two facies of the rock in the hand specimen is slightly irregular but sharp. Under the microscope it is also seen to be fairly sharp, but the quartzes and feldspars of the borders show a tendency to granularity and passage into the aplite which is suggestive of crystallization out of one magma and not that due to two injections. This idea of differing crystallization in one magma is also supported by the uniformity with which the aplitic band sustains its central symmetrical position with reference to the two sides. The highly anomalous character of the dike will have been noticed, in that the borders, contrary to the usual rule, are more coarsely crystalline than the central portion. If we adopt Judd's[1] view of the composite dikes

[1] J. W. JUDD, Q. J. Geol. Soc., Vol. XLIX, p. 536, 1893.

of Arran it is easy to explain this by assuming that the first-formed dike cracked down its center, and that this crack was filled by a later injection, which, cooling rapidly, solidified as aplite. This is not the place to enter into a discussion of the subject, but it may be said that in view of the facts noted above, the similarity in chemical composition of the two portions, and for other reasons, this explanation does not seem to be the correct one, and we are forced to conclude that the dike is due to only one injection. In this case the coarser crystallization at the borders may be due, as Professor Iddings has suggested to me, to the presence of mineralizers derived from the surrounding granite, or, as seems to me more probable, to certain peculiar physical and chemical conditions which I hope to explain in another place.

	I	II	III	IV
SiO_2	77.49	76.44	77.14	77.61
TiO_2	0.25	0.37	0.29	0.25
Al_2O_3	11.89	12.95	12.24	11.94
Fe_2O_3	0.34	0.19	0.29	0.55
FeO	1.12	0.89	1.04	0.87
MnO	trace	trace	trace	trace
MgO	0.09	trace	0.06	trace
CaO	0.45	0.15	0.35	0.31
Na_2O	4.58	4.76	4.64	3.80
K_2O	4.26	4.95	4.47	4.98
H_2O (110°)	....	....	....	trace
H_2O (ignit.)	0.16	0.09	0.14	0.23
	100.63	100.79	100.66	100.54

I. Aplite. Border of Dike. Bass Rocks. H. S. Washington anal.
II. Aplite. Center of Dike. Bass Rocks. H. S. Washington anal.
III. Aplite. Composition of whole dike, two parts of I, one part of II.
IV. Granite. Rockport. H. S. Washington anal. JOUR. GEOL., VI, p. 793, 1898.

Analyses were made both of the border and of the center and are given above in I and II. The composition of the dike as a whole, calculated from two parts of I and one part of II, is given in III. The two parts of the dike are seen to be sensibly identical in composition, the border with a little more silica, lime and magnesia, and a little less alumina and alkalies. The

composition of the dike as a whole is remarkably similar to that of the granite of the region (analysis IV), the only noteworthy difference being in the soda.

Quartz-syenite-porphyry.— Dikes of this are met with in considerable numbers in the granite areas, especially that of Cape Ann, where they have been mapped by Shaler.[1] The best specimens in my possession come from the dikes numbered by Shaler 52, 53, and 70 on Eastern Point, and 245, a short distance north of Squam Light, the last being the freshest. Megascopically they show phenocrysts of alkali-feldspar, hornblende and biotite, and fewer of quartz; scattered through a fine-grained groundmass composed of feldspar, some quartz and specks of ferromagnesian minerals. The specimen from near Squam Light is a rather dark ash-gray, while the others are brownish-gray.

Under the microscope the large feldspars are seen to be microperthitic and are all cloudy and somewhat decomposed. The large hornblendes are ragged in outline and usually slightly altered, brown limonitic flakes being seen at their edges. They are of a peculiar, rather vivid grass-green, resembling that of actinolite, and are quite pleochroic. A few ragged plates of greenish-brown biotite are seen as phenocrysts. The groundmass is granitic and holocrystalline, the quartzes clear and generally interstitial between the feldspars. These are almost entirely of orthoclase or soda-orthoclase, not usually microperthitic, with a few doubtful oligoclases. They show a marked tendency to automorphic development. Irregular shreds of hornblende and biotite, similar to those forming the phenocrysts, are quite common, the former being the more abundant. A few small grains of magnetite and titanite are seen here and there and minute needles of apatite are fairly common.

For analysis the freshest specimen from Dike 245, north of Squam Light, was chosen, the result being given below, with that of the Wolf Hill nordmarkite for comparison.

[1] SHALER, Ninth Ann. Rep. U. S. Geol. Surv. Plate LXXVII.

	I	II	III
SiO_2	68.88	68.36	69.00
TiO_2	trace	trace	0.35
Al_2O_3	14.96	16.58	13.95
Fe_2O_3	0.64	0.90	1.56
FeO	4.64	3.24	2.38
MnO	trace	trace	0.55
MgO	0.37	0.45	0.14
CaO	1.74	1.85	0.49
Na_2O	3.83	3.97	5.67
K_2O	4.97	5.27	5.11
H_2O (110°)	0.06	0.18	....
H_2O (ignit.)	0.24	0.17	0.70
	100.33	100.97	99.95

I. Quartz-Syenite-Porphyry. Squam Light. H. S. Washington anal.

II. Nordmarkite. Wolf Hill, Gloucester. H. S. Washington anal. JOUR GEOL., VI. p. 800, 1898.

III. Lindoite. Frön, Norway. V. Schmelck anal. Brögger: Eruptivgest. des Krist. geb. I, p. 139, 1894.

The composition is rather acid, with high alkalies and rather high lime, with ferrous oxide largely in excess over ferric, and is closely similar to that of the nordmarkite. These dikes resemble in certain ways the lindoites of Brögger, which are acid bostonitic rocks. This is seen from the chemical point of view by comparison of I and III, that of the Essex county rock differing materially only in the slightly higher lime. Mineralogically they also resemble each other closely, though blue arfvedsonite or riebeckite is common in the lindoites, while the hornblende here is a peculiar green with only a tinge of blue. One specimen of lindoite in my possession from Huk in the Christiania Fjord, collected under the guidance of Professor Brögger, shows greenish-brown hornblende with some biotite, and does not differ radically from the present dike rocks. Structurally also the two resemble each other, the groundmass feldspars being quite automorphic in stout tables, the quartz interstitial and the hornblende irregular.[1] We do not, however, find in our rocks the zircon which is so common in the Norway

[1] Cf. BRÖGGER, *op. cit.*, I, Fig. 15, p. 137.

rocks. These dike rocks might then with propriety be called lindoite, but in view of their more porphyritic character and for other reasons they will be referred to as quartz-syenite-porphyry.

In this connection must be described two rocks found cutting the gabbro at Nahant. The one, which occurs at Little Nahant, is fine-grained, scarcely porphyritic, mottled gray, pink and green, and is evidently considerably altered. It is essentially a hornblende-biotite-quartz-syenite, and resembles in most particulars the rocks just described. The feldspar is apparently mostly orthoclase, and the hornblende is of a similar peculiar green, not highly pleochroic, and much of it seems to be secondary. The biotite, which is primary and which occurs in smaller amount, is the most notable feature. It occurs as stout crystals with ragged edges, often partially altered to the green hornblende. Its color is greenish-brown, and the strong pleochroism is very striking and unusual; parallel to the cleavage deep grass-green, perpendicular to this reddish yellow-brown, the absorption in the former direction being much the stronger.

The second rock, which is found at the road-metal quarry at Nahant as narrow dikes and small "schlieren" in the gabbro, is a compact, almost aphanitic, rather dark gray rock without phenocrysts. In thin section it shows a multitude of small isodiametric crystals of biotite having a peculiar light yellowish color and usual absorption scheme. With these are very many small colorless diopside anhedra, which in parts of the slide become more numerous. These, together with many magnetite grains and some small apatite needles, are embedded in a colorless or slightly yellow mass, which between crossed nicols is seen to be composed of tabular orthoclase crystals with fewer of a twinned oligoclase, the mesostasis being in patches either alkali-feldspar or quartz, the latter less abundant. In places the feldspar mesostasis extinguishes simultaneously over large areas and becomes poikilitic in character, and in these areas automorphic feldspar crystals are wanting. The tabular feldspars are in fact best developed and sharpest when surrounded by interstitial quartz, when in feldspar they are much less well

defined and more uncertain in outline. The structure as a whole is a rather peculiar one. The rock would seem to be not very acid and with rather high potash, and its occurrence in connection with the gabbro (which it will be remembered also carries some orthoclase) is noteworthy.

A rock which is essentially an *alkali-syenite-porphyry* occurs as a dike on the southeast coast of Marblehead Neck cutting the rhyolite. It somewhat resembles a minette, though rather more acid. Hornblende is absent, diopside rare, and small stout crystals of biotite abundant. These are usually a peculiar light brown and pleochroic, but some are seen of a pale green, slightly bluish in tone, and with feeble pleochroism. This variety also occurs intergrown with the brown, and may be a bleached form of the latter, but it resembles closely the similarly colored biotite found in some of the granites, especially that of Marblehead Neck itself. The groundmass of alkali-feldspar is granular, much of it being decomposed with formation of kaolin. A few grains of probably secondary quartz are present.

PAISANITE-SÖLVSBERGITE-TINGUAITE SERIES

A small but very interesting group of dike rocks is distinguished mineralogically by the combination of alkali-feldspar and either glaucophane-riebeckite or aegirite. These carry abundant quartz at the acid end of the series (paisanite), little or no quartz in the intermediate members (sölvsbergite), and nepheline in the most basic (tinguaite). This series, it will be observed, corresponds very closely to Brögger's Grorudite-Sölvsbergite-Tinguaite series from the Christiania region.[1] As far as my observations go, these dikes are not very wide, a few feet at the most. Nearly all my specimens are from dikes cutting granite, either on Cape Ann or along the Manchester-Magnolia shore; one specimen only is from the foyaite area of Salem Harbor.

Paisanite.—The only example of this rock which I found is Shaler's dike No. 3, at the extreme southeast corner of Magnolia

[1] BRÖGGER, *op. cit.*, I.

Point, near the water's edge, which was called by him a quartz-porphyry, and was briefly described by Tarr. It has a width of ten feet, with a strike of N. 2° E. It is cut by a narrow dike of dense black diabase.

The rock is compact, with practically no change in texture throughout its width. Phenocrysts of white or yellowish alkali-feldspar, up to 1.5 cm. in diameter, and smaller smoky bipyramids of quartz are thickly sprinkled through a very fine-grained, rather dark blue-gray groundmass. By the action of the waves and the sea water, with which most of the dike is covered at high tide, the groundmass has been dissolved, and on these surfaces the beautifully sharp and automorphic phenocrysts of feldspar and quartz stand out prominently. The feldspars are stout, prismatic, parallel to the axis *a;* are frequently twinned according to the Carlsbad and also the Manebach laws, and show a number of planes. They will be examined crystallographically later.

Under the microscope the sections present a striking appearance. The sharp quartz phenocrysts are clear, with occasional streaks of minute gas or liquid inclusions, and not infrequently carry rounded inclusions of granular feldspar, or feldspar and glaucophane, like the groundmass; while here and there isolated crystals of glaucophane are also seen. The highly automorphic feldspars are uniformly microperthite, or microcline-microperthite, no plagioclase being seen. They are dusty with minute, often rod-shaped, microlites of a colorless transparent substance, the nature of which is difficult to determine, and are stained, especially at the edges, with limonite. They carry inclusions of glaucophane crystals, or small groundmass patches, which occasionally show a well-developed micrographic structure. There is little evidence of magmatic corrosion, especially in the feldspars, though the quartzes show a tendency to rounded angles and shallow embayments.

The groundmass is very fine-grained, and is composed of minute needles of dark greenish-blue hornblende, up to .01 mm. in length, strewn pellmell in a granular mass of feldspar and quartz. Neither magnetite nor apatite was seen, nor is any

glass present. Along the borders of the phenocrysts, both quartz and feldspar, the hornblende needles are smaller and crowded together, as if pushed aside by the growth of the large crystal, in a manner quite analogous to that described by Pirsson[1] in the case of a tinguaite from the Bearpaw Mountains. There is no evidence of flow structure in the proper sense of the term.

The hornblende is apparently a glaucophane-riebeckite, identical with that described elsewhere[2] in a sölvsbergite from Cape Ann. The extinction angle is small, pleochroism intense; parallel to the axes *c* and *b* dark blue-gray; parallel to axis *a* pale yellow. The position of the axes of elasticity could not be definitely determined, but apparently **c** lies nearest to *c*, indicating that it is a glaucophane.

An analysis of this rock is given below, together with one of the Texas paisanite and one of a grorudite from Norway. The paisanites were discovered by Osann as dikes in Transpecos, Tex., and named after the Paisano Pass, where the types were found. They are composed of quartz, alkali-feldspar, and riebeckite, in the Texas rocks this last forming blue spots in a white groundmass, and quartz and feldspar being also phenocrystic.

	I	II	III
SiO	76.49	73.35	74.35
TiO_2	trace	....	....
Al_2O_3	11.89	14.38	8.73
Fe_2O_3	1.16	1.96	5.84
FeO	1.56	0.34	1.00
MnO	trace	....	0.22
MgO	trace	0.09	0.07
CaO	0.14	0.26	0.45
Na_2O	4.03	4.33	4.51
K_2O	5.00	5.66	3.96
H_2O (110°)	0.12	....	....
H_2O (ignit.)	0.38	....	0.25
	100.57	100.37	99.38

I. Paisanite, Dike 3, Magnolia. H. S. Washington anal.

II. Paisanite, Mosquez Canyon, Transpecos, Texas. A. Osann. Tsch. Min. Pet. Mitth. XV, p. 439. 1895.

III. Grorudite, Varingskollen, Norway. Särnström anal. Brögger, *op. cit.*, I, p. 48, 1894.

[1] Pirsson, Am. Jour. Sci. (4), II, p. 191, 1896.

[2] H. S. Washington, Am. Jour. Sci. (4), VI, p. 177, 1898.

The analyses of the two paisanites resemble each other closely, the main differences being in silica, alumina, and ferrous oxide. These rocks are analogous to the grorudites of Brögger, which, however, carry aegirite in place of soda-hornblende, and which are rather less acid than the Magnolia rock. The replacement of alumina by ferric oxide in the grorudite is to be noticed. The phenocrysts differ also in being alkali-feldspar, aegirite, and hornblende, while quartz occurs only in the groundmass, and the color of the rock is dark green, rather than blue, owing to the abundant aegirite.

Sölvsbergite.—The rocks belonging to this group are characterized by the presence of alkali-feldspar with aegirite or a soda-hornblende, with occasional biotite and very little or no quartz. In Norway the structure is generally trachytic, which is not the case in Essex county, but the similarity otherwise, both mineralogically and chemically, is so great that this structural difference may be overlooked.

The Essex county sölvsbergites are fine-grained and compact, not very porphyritic, and of a gray or blue-gray color. As the various dikes show rather diverse characters, they may be described separately.

One of these, from Dike 184, at Andrew's Point, Cape Ann, has already been described[1] as composed essentially of feldspar and glaucophane-riebeckite, with very little quartz. At that time, however, only sections from the border of the dike were available. Since then I have studied sections from the center as well with interesting results. The borders of the four-foot dike are very fine-grained and compact and of blue-gray color. At the center the rock becomes coarser, but is still fine-grained, and is composed of small black specks in a light gray groundmass.

Examining the sections under the microscope, it is seen that in the borders the hornblende is nearly constantly glaucophane, yet, as we approach the center, there are found streaks in which a bright grass-green aegirite partly replaces it. At the center the grain is larger, and the feldspars tend to become automor-

[1] H. S. WASHINGTON, Am. Jour. Sci. (4), VI, p. 176, 1898.

phic, the development being thick tabular, and a radiated arrangement quite common. The dark blue hornblende is present here in larger grains, but less abundant, while the green pleochroic aegirite, showing the usual characters is fully as abundant as it, and in places more so. The aegirite does not occur in needles, but mostly in stout, irregular anhedra, and only occasionally in rough prisms. Small crystals of a yellow-brown, highly pleochroic biotite are also seen. There are also numerous small, slender needles of a bright yellow pleochroic mineral, often arranged in stellate groups. Their pleochroism varies with the depth of their color, the deepest showing a reddish-yellow parallel to the length, and a lighter greenish-yellow perpendicular to this, while the paler ones show scarcely any pleochroism. These are the same which were thought to be either apatite or rosenbuschite in the former description, but here their larger size and more intense coloration permits of a better examination, and it seems that they are to be referred to astrophyllite.

A sölvsbergite of a somewhat different type is that forming Shaler's Dike 182, near Pigeon Cove, on Cape Ann. The dike itself is three to four feet wide, with strike N. 73° W. At one place a tongue of granite about ten feet in length protrudes into the dike. In this tongue, as well as immediately outside for a distance of twenty feet along the dike and a foot from it, the granite has been squeezed, and a gneissoid structure developed, the foliations on the outside bending around towards the tongue and being parallel to its length within it. Examined in thin section, the quartz and feldspars of this gneissoid granite are seen to have been squeezed, crushed, cracked, and frequently drawn out into lenticular shapes, exactly as in many gneisses. It is remarkable that such a squeezing should have taken place over such an extremely limited area, the granite outside of the gneissoid portion and on the other side of the dike being absolutely normal in character.

But to return to the dike. This is dark gray and compact, with a few small phenocrysts of aegirite and feldspar. In thin section, it is seen to be composed of a pale greenish hornblende,

pleochroic in light tints of blue-green and yellow-green, and with an extinction angle of 15°, partly in large, stout phenocrysts, but mostly as small, irregular grains, with small, stout flakes of a peculiar light brownish-gray biotite, embedded in microperthitic feldspar, generally in anhedra, but occasionally showing roughly tabular forms. Neither aegirite nor the normal blue hornblende is to be seen, nor was any quartz found.

A very pretty sölvsbergite forms Dike 55, which cuts the granite at the pier of the Hawthorne Inn, East Gloucester. The rock is aphanitic and chiefly a dull gray, but is mottled with streaks of white or greenish-gray, which run parallel to the walls. Under the microscope the only phenocrysts visible are a few sharply automorphic ones of alkali-feldspar, which are composed of orthoclase and albite, not arranged microperthitically, but forming aggregates of small granular anhedra. This structure seems to be due to secondary processes, as the rock is not quite fresh, and the sharp crystal outlines of the aggregates show that they were originally well-defined crystals. The groundmass is composed of a finely granular alkali-feldspar, possibly with a little quartz, thickly sprinkled with small blue or green needles. Most of these are of bluish-gray glaucophane, and are of two sizes. The smallest, usually less than .01 mm in length, tend to accumulate in rounded patches or streaks, surrounded by clearer feldspar carrying sparsely scattered, larger needles. Other streaks occur in the sections, corresponding to the pale streaks seen in the hand specimen, which are of feldspar carrying pale green aegirite needles and grains, with little, if any, glaucophane. In one place the orthoclase and albite are intergrown radially, forming sphaerocrystals which give a black cross between crossed nicols.

Another sölvsbergite, the specimen of which I owe to the kindness of Mr. Sears, occurs as a dike at West Cove, Coney Island, in Salem Harbor. This has been described by Rosenbusch, who calls it a bostonite-porphyry.[1] To a certain extent,

[1] ROSENBUSCH, Mikr. Phys., Vol. II, p. 425; also Elemente der Gesteinslehre, 1898, p. 198, where it is called "bostonitic alkali-syenite-porphyry."

my specimen agrees with his descriptions, especially as to the megascopical appearance, the feldspars and the flow structure. But there is a marked discrepancy in the colored components, and it is evident that here also the dike varies in character in different parts, assuming that the two specimens came from the same dike. From analogy with the Andrew's Point dike, it would seem that Rosenbusch's specimen came from the border, while mine came from near the center.

The rock is rather dark gray, fine-grained, and, in my specimen, with little suggestion of silky luster. The tabular alkali-feldspar phenocrysts are identical with those described by Rosenbusch. This author speaks of a blue glaucophane-like hornblende as the only colored component. In my specimen this occurs very sparingly, its place being taken by a highly pleochroic, peculiar olive-green hornblende, bright green aegirite grains, and flakes of a greenish-brown, intensely pleochroic biotite. Generally these are scattered uniformly through the section, but in places one or the other predominates. A few phenocrysts of colorless diopside are seen, surrounded by a narrow border of aegirite. A number of fair-sized titanite grains and a few apatite needles are present, but quartz is wanting. Flow-structure is very pronounced, and is well brought out between crossed nicols, on account of the highly tabular development of the groundmass feldspars.

The last of the sölvsbergites to be described was found as blocks in a wall along the back road southwest of Bass Rocks. It is very dense and compact and of a deep bluish-gray color. Under the microscope no phenocrysts are visible, and practically the only colored component is a deep blue glaucophane, which occurs in abundant needles or stout prisms. There are also present, in extremely small amount, small grains of colorless diopside, but no aegirite, biotite, or green hornblende. The rock is chiefly remarkable for its colorless base, which is composed of alkali-feldspar, with considerable quartz — enough to justify the name quartz-sölvsbergite. These are partly irregularly granular, but also form small patches with micro-

graphic texture, which are highly characteristic and very abundant.

The provenance of these blocks is not known, but they probably come from a dike in the immediate vicinity. Search revealed an outcrop of a dense, very pale gray dike, with only a slight tinge of blue, near a small pond across the road. This is evidently a bleached-out sölvsbergite, since the microscope reveals the fact that the small, originally blue, hornblendes are nearly all entirely decomposed to an opaque black substance, with little change of form, and small crystals of diopside are also possibly derived from them. This rock also shows the peculiar and striking micrographic patches, and it is therefore highly probable that the wall blocks were obtained from freshly blasted portions of this dike.

Only two analyses have been made by me of these rocks, which are given below. For comparison there are quoted an analysis of the Coney Island dike recently published by Rosenbusch, as well as two analyses of Norwegian sölvsbergites.

	I	II	III	IV	V
SiO_2	64.28	61.05	60.60	62.70	64.92
TiO_2	0.50	0.34	0.71	0.92	....
Al_2O_3	15.97	18.81	18.28	16.40	16.30
Fe_2O_3	2.91	2.02	2.85	3.34	3.62
FeO	3.18	3.06	2.67	2.35	0.84
MnO	trace	trace	....	trace	0.40
MgO	0.03	0.42	0.52	0.79	0.22
CaO	0.85	1.30	0.99	0.95	1.20
BaO	none	none	....	....	....
Na_2O	7.28	6.56	6.66	7.13	6.62
K_2O	5.07	6.02	5.73	5.25	4.98
H_2O (Ignit.)	0.20	0.78	0.69	0.70	0.50
P_2O_5	0.08	....	0.15	....	....
	100.33	100.04	99.85	100.53	99.60

I. Sölvsbergite. Dike 184, Andrew's Point, Cape Ann. H. S. Washington anal. Amer. Jour. Sci., (4) VI, p. 178, 1898.

II. Sölvsbergite. Dike. Coney Island, Salem Harbor. H. S. Washington anal.

III. Sölvsbergite ("Bostonitic Alkali-syenite-Porphyry"). Coney Island. M. Dittrich anal. Rosenbusch, Elem. d. Gest. lehre., 1898, p. 199, No. 3.

IV. Katoforite-Sölvsbergite. Lougenthal, Norway. L. Schmelck anal. Brögger, *op. cit.*, I, p. 80.

V. Aegirite-Sölvsbergite. Sölvsberget, Gran, Norway. L. Schmelck anal. Brögger, *op. cit.*, p. 78.

The Andrew's Point sölvsbergite is rather acid and approaches closely the katoforite-sölvsbergite from the Lougenthal. It resembles the Coney Island dike in its main features, especially in the high alkalies and the relations of the iron oxides. The two analyses of the Coney Island dike resemble each other very satisfactorily, and show that it is rather more basic, approaching the Kjöse-Aklungen dike, which, however contains a little nepheline. It is evident from these analyses and the descriptions given that the Coney Island rock is really a sölvsbergite and not a bostonite-porphyry, for which indeed, as Rosenbusch himself remarks, it carries an abnormally large amount of colored minerals.

Tinguaite.— The most basic members of the series we are now discussing, the tinguaites, which are not abundant in Norway, occur very sparingly in Essex county, only three dikes of this rock having come to my notice.

One of them, an analcite-tinguaite, from Pickard's Point near Manchester, has been already described.[1] It is aphanitic and olive-green, with only rare phenocrysts of feldspar in a groundmass of aegirite needles, alkali-feldspar, nepheline and analcite. The perfect freshness of the rock, as well as theoretical considerations, lead to the conclusion that the analcite is primary.

The second tinguaite occurrence is that recently described by Dr. A. S. Eakle[2] as a biotite-tinguaite from Gale's Point near Manchester. It is composed of alkali-feldspar, nepheline, kaolin and secondary quartz, aegirite, and a little biotite and magnetite. As Dr. Eakle points out it approaches the nepheline-bearing sölvsbergite from Kjöse-Aklungen already mentioned, and might be classed with the sölvsbergites.

The third occurrence of tinguaite is a dike two hundred yards east of Squam Light, discovered by Mr. Sears, to whom I am indebted for a specimen, The rock is dark green and very dense. This is also a biotite-tinguaite and very fresh. No phenocrysts are visible. Abundant small irregular grains and

[1] H. S. WASHINGTON, Am. Jour. Sci., (4), VI. p. 182, 1898.

[2] A. S. EAKLE, Am. Jour. Sci., (4), VI, p. 489, 1898.

prismatic crystals of aegirite with fewer small flakes of brown biotite, are strewn in a colorless base composed of small tabular alkali-feldspars with interstitial nepheline. Colorless needles of what is probably diopside are also present, but no magnetite was seen. The rock shows a well marked flow structure.

Of these rocks we have two analyses, both already published, one of the Pickard's Point analcite-tinguaite, the other of the biotite-tinguaite. With them are given for comparison analyses of the border and center of the Hedrum tinguaite dike and the Kjöse-Aklungen sölvsbergite.

	I	II	III	IV	V	VI
SiO_2	56.75	60.05	56.58	55.65	58.90	54.22
TiO_2	0.30	0.11	....	....	0.40	0.38
Al_2O_3	20.69	19.97	19.89	20.06	17.70	20.20
Fe_2O_3	3.52	4.32	3.18	3.45	3.94	2.35
FeO	0.59	1.04	0.56	1.25	2.37	1.02
MnO	trace	0.79	0.47	....	0.55	0.19
MgO	0.11	0.23	0.13	0.78	0.54	0.29
CaO	0.37	0.91	1.10	1.45	1.05	0.70
BaO	none	....	....	....	....	trace
Na_2O	11.45	7.69	10.72	8.99	7.39	9.44
K_2O	2.90	3.24	5.43	6.07	5.59	4.85
H_2O (110°)	0.04	0.15	....	....	....	0.42
H_2O (ignit)	3.18	1.26	1.77	1.51	1.90	5.57
Cl	0.28	0.28	....	....	....	P_2O_5 0.11
	99.92	100.04	99.83	99.21	100.33	99.74

I. Analcite-Tinguaite, Pickard's Point. H. S. Washington anal. Trace of SO_3. Am. Jour. Sci. (4), VI, p. 185, 1898.

II. Biotite-Tinguaite, Gales Point. A. S. Eakle anal. Am. Jour. Sci. (4), VI, p. 491, 1898.

III. Tinguaite (dike border). Hedrum, Norway. G. Pajkull anal. Brögger, *op. cit.*, I, p. 113.

IV. Tinguaite (dike center). Hedrum. V. Schmelck anal. Brögger, *op. cit.*, p. 191.

V. Nepheline-Sölvsbergite. Kjöse Aklungen, Norway. V. Schmelck anal. Trace of P_2O_5. Brögger, *op. cit.*, p. 102.

VI. "Phonolite" (Tinguaite?) H. N. Stokes anal. Southboro, Mass. Bull. 148. U. S. G. S., p. 77.

In I the only points which need be mentioned here are the rather low silica, high soda, and, for so fresh a rock, the high

content of water. It very closely resembles the Hedrum border rock, except in water and potash. The biotite-tinguaite is more acid, and closely corresponds in general features to the analysis of the Coney Island sölvsbergite. The characteristic distinction, however, is found in the relative amounts of the iron oxides and in the alkalies. In these respects the two tinguaite analyses resemble each other, and these two features, taken together, serve to differentiate their analyses from those of the more basic sölvsbergites. This whole series presents several points of interest, as regards the relations of the various members to each other, and their relative composition, but discussion of these features will be deferred to a later page. In connection with these rocks I may call attention to a so-called phonolite from Southboro, Mass., whose analysis is given in VI. Although not described an examination of sections of specimens kindly sent me by Professor B. K. Emerson proves that they are typical aegirite-tinguaites, one specimen showing very sharp nepheline crystals.

HENRY S. WASHINGTON.

(To be Continued)

THE DISTRIBUTION OF LOESS FOSSILS

It has perhaps been noted that the loess molluscs thus far reported in the literature of the subject are, for the most part, from localities in close proximity to the larger streams. This fact may have suggested the thought to those unfamiliar with the modern habits and present distribution of these molluscs that the adjacent streams had in some way something to do with the entombing of the shells now found in the loess. That the loess is most richly fossiliferous near streams is generally, though not always, true. The abundance of fossils is a decidedly variable quantity. There are exposures near streams which exhibit fossils in profusion, and others which are wholly barren. On the other hand, exposures quite remote from streams contain fossils —though in such situations a proportionately much larger part of the loess is entirely devoid of them.

This fact has sometimes led geologists to attempt to distinguish, in varying degrees, between the loess adjacent to streams and loess more remote. Whatsoever distinction may be observed in the physical characters of the loess of various deposits,[1] no distinction can be based on the presence or absence of fossils alone. The simple fact that one deposit is fossiliferous and another is not, does not prove, nor even indicate, that the deposits were formed under wholly, or even materially different circumstances. In the one case there are no fossils simply because there were no shells to be buried; in the other, fossils are common because shells were abundant on the old land surfaces, where they were covered as other imperishable objects would have been covered.

Fossils are more abundant in the vicinity of streams because

[1] For one of the most recent discussions of the loess with reference to its variation according to distance from streams, see Dr. Chamberlin's article in the Jour. Geol., Vol. V, No. 8, p. 795.

the same species thrive, and in all probability did thrive in the past, in just such situations.

Manifestly, if we would judge of the conditions under which the fossils existed and were finally buried in the past, we must understand the conditions under which the same species exist today. It has already been pointed out by the writer[1] that the loess fauna of any section of the country closely resembles the modern molluscan fauna of the same section, the characteristic fossil species being for the most part characteristic species of the modern fauna. During the past summer the writer made more extended studies of fossils in widely separated loess regions, notably in Mississippi, Iowa (both eastern and western), and Nebraska, which strongly emphasize the foregoing fact. As questions of general geographical, as well as local, distribution of fossil and modern molluscs are of great importance in connection with any attempt at an explanation of the manner in which loess was deposited, the following remarks are offered as preliminary to further detailed reports upon the distribution of the loess species and of their modern representatives.

In Iowa and Nebraska, as elsewhere, the land shells form the characteristic fauna of the loess, and with two or three exceptions the same species may be found living within the borders of our state today.

The student who goes to the field to study the living forms in their natural environment, if his studies be sufficiently extended, will be struck by the many seeming eccentricities in distribution. He will, however, observe that our land molluscs as a rule favor the regions adjacent to streams — especially the rough, rugged hills which so often border them. This fact, however, seems to be dependent upon another, equally interesting and long well known — namely, that our timber areas for the most part skirt the streams — and that this distribution of vegetation determines largely the distribution of the molluscs is shown by the fact that the timber or brush-covered areas remote from streams are quite likely to yield plenty of shells. A few

[1] Proc. Iowa Acad. of Sciences, Vol. V, pp. 33, 41.

species (as for example *Succinea grosvenorii*) seem to favor open, rather grassy places, and a few others may be found among the weeds and bushes skirting prairie ponds, but as a rule rough, rolling timber areas are favored. Here an abundance of food (for nearly all are herbiverous) and more or less shade and protection are furnished by the vegetation. As we recede from the timber-bordered streams the number of species and specimens grows less, and the writer knows from personal experience obtained in various parts of the state that large prairie areas of that character may be searched in vain for any trace of a land mollusc. In the eastern part of the state, with its more rolling, timber-covered surface, almost every locality — certainly every county — presents numerous favorable locations for colonies of snails, but as the collector crosses the state westward he finds that in species and in specimens the molluscan fauna grows poorer, the timber-fringed streams or ponds and lakes alone marking the favorable localities.

If careful observations are made even in the best of these collecting grounds, whether in the eastern or western parts of the state, it will be found that much variation and inequality in local distribution exist. One hillside may present certain species, while the next, perhaps across a narrow ravine, will show a wholly different series, and a third near by may have none at all. A species which in one spot is the prevailing type, may, only a few rods or even feet away, be wholly or in part supplanted by another. This is sometimes due to differences in the abundance of trees and vegetation furnishing food, and to other variations in the character of the surface, but often it seems to be a mere accident.

The number of individuals of any, or all, species in a given locality is also very variable. In the most favorable spots, however, especially on higher grounds, one seldom finds many individuals together. Even such species as *Zonitoides arboreus*, *Z. minusculus*, *Vitrea hammonis*, *Cochlicopa lubrica*, *Succinea obliqua*, *S. avara*, etc., which may often be found in large numbers under leaves or sticks and logs in comparatively low places, usually show

fewer and more scattered specimens on hillsides, etc., especially in more open places. To get a good set of any species in such localities the collector must work over a considerable area, but in doing so he will almost invariably find individuals of several species mingled promiscuously. If he compares the molluscan faunas of the eastern and western parts of the state, he will find that, as stated, the number of species and individuals in the eastern part is, as a rule, greater. He will also find that there are certain rather striking differences between sets of some of the species taken at opposite extremities of the state. Those from the eastern part are likely to average larger in size and to be thinner shelled, resembling more nearly representatives from the eastern part of the country, while the western forms are smaller and heavier. This is especially true of *Polygyra mutilineata*, *Zonitoides minusculus*, *Succinea obliqua*, *S. avara*, and other species of the kind which are sometimes found in rather low places, but which also occur on higher grounds—especially westward. This is probably due chiefly to the scarcity of forests in the western and central parts of the state, where the rather scant groves usually consist of scattered and stunted trees, being quite different from the more vigorous forests of the eastern part. That this view is correct is further attested by the fact that the same species of molluscs, when occurring on comparatively barren or nearly treeless areas in the eastern part of the state, usually show the characters of the western types, namely, the smaller size and sometimes heavier, or at least more compact shell.

If the student will study the molluscs of a given region for a number of years, he will find that from year to year the abundance of the several species varies, some even running out entirely, while others unexpectedly appear. The writer has watched a number of localities near Iowa City for many years, and has found this variation often striking.

If, now, the distribution of the fossils in our loess is compared with that of the modern shells, a remarkable similarity is evident. The best collecting grounds are near streams, while the clay of the remote prairie is usually barren. Where fossils

are abundant one exposure contains species of one kind, another near by presents a new, or at least a different list, while still another has none—and the same variation which may be observed in the local distribution of the recent shells in any restricted locality, will be exhibited in individual exposures of fossiliferous loess.

In horizontal distribution the fossils show the same mode of distribution as that already noted in the modern forms. The specimens are not heaped together, but are scattered about like the modern shells, usually a number of species mingled together, but in unmodified loess invariably *not* crowded, so far as the writer's observations have gone.

The vertical distribution of the fossils also conforms to the surface distribution of the modern shells. If the loess was not deposited *in toto* at once, and this seems to be conceded, there were successive land surfaces upon portions of which shells grew. These shells varied from time to time in number, some persisted during long periods, some disappeared and others took their places. If we study the vertical distribution of the fossils in the loess the same variation in the succession of species is observed. Some species occur throughout the thickness of a particular exposure, but more frequently a part of the loess is without fossils, certain species occupy a part of the deposit, while above or below them are other species—as though the varying generations of surface species had been successively buried in the deposit. The number of specimens upon any one of the successive land surfaces was not very great even in richly fossiliferous loess, for if we draw lines approximately parallel to the present surface to represent the successive surfaces, we will find that in any one of them but few fossils occur.

Where depauperation or variation in size is noticeable in the fossils, it will be found that it takes place in the direction of the western modern forms. For example, while the common modern *Polygyra multilineata* at Iowa City is large, the common fossil form is small, though the small modern and the large fossil forms are also occasionally found, but not respectively with the

preceding forms. On the other hand, at Council Bluffs and Omaha the modern shells of this species are usually small, like those of the loess, though both fossil and modern shells of the large type occasionally occur. Thus the fossils of this species from the eastern part of the state resemble both the fossil and modern shells from the western part. *Succinea avara* is another example. The small typical form is common in the loess at Iowa City, but the modern shells are not frequent, occurring always on more or less wooded hillsides, while westward the type is the common modern form.

In the loess of both the east and the west,[1] *Sphyradium edentulum alticola, Pyramidula strigosa iowensis,*[2] *Succinea grosvenorii*, forms belonging now to the dry western plains, are quite common. Their presence, together with that of the "depauperate" forms, when considered in connection with the entire molluscan faunas of the eastern and western parts of the state, suggests a climate considerably drier than that of the eastern part of the state, and a surface less abundantly timbered. Certainly both modern and fossil faunas unmistakably show[3] that the conditions in the eastern and western parts of Iowa during the deposition of the loess were approximately included within the bounds of the present extremes presented by these regions, and that any attempt to drag into the discussion of this subject conditions either of a glacial climate or of frequent and widespread floods and inundations, or of any excess of moisture, is gratuitous.

The conditions which cause the depauperation of our shells exist more or less all over Iowa today, especially westward, and yet we do not have a glacial climate. If the molluscs

[1] The loess herein designated as "eastern" is that of eastern Iowa — the "western" being that of western Iowa and eastern Nebraska.

[2] This form has heretofore been reported as var. *cooperi* which lives abundantly in the far West, but Pilsbry regarded it as extinct and distinct, and has described it under the name *iowensis*. All living forms of *strigosa* belong to the high, dry regions of the West. Neither of these species was found at Council Bluffs, but both are found in the loess of Nebraska. *Sphyradium* was formerly included in *Pupa*.

[3] See also the writer's paper in Proc. Ia. Acad. Sci., Vol. V.— particularly p. 42.

of the loess be used as an absolute measure of the amount of moisture occurring during loess times, then we must conclude that Iowa was without streams, for practically no fluviatile molluscs occur in the loess, and that there were but few ponds in which aquatic molluscs found a favorable habitat, for even aquatic Pulmonates are rare in the loess,[1] the number of terrestrial forms being out of all proportion to that of the aquatic forms.

During the past summer the writer collected several thousand specimens in the loess of Mississippi and western Iowa, and among them all there were not a half dozen aquatic shells. A list of the modern shells of Iowa shows a large number of aquatic species, yet few of these occur in the loess. There is also among the modern terrestrial forms a large number of those which occur only in very damp places—and these, too, are almost wholly missing from the loess. The writer is well aware that many of the forms found in the loess are often referred to as aquatic or "semi-aquatic," or at least as favoring very wet situations. But evidence of this character has been furnished largely by those who are familiar only with the molluscan fauna of the eastern part of the country, where the amount of rainfall is much greater, and where surface conditions are not the same as in Iowa and Nebraska—or it has come from so-called "closet-naturalists." Now, the "closet-naturalist" has done abundant harm in this as in other branches of science. Too remote, often, from the phenomena under discussion, or too dainty to soil his fingers with the toil and the exposure of field-work, he has passed judgment upon the habits of forms which he knew only from material submitted by mail—or still worse, he has taken the work of others and, not appreciating the significance of the facts so borrowed, has distorted them to do menial service in the encouragement of some pet notion.

In the particular case in hand no distinction has been made between the habits of the depauperate varieties and the larger

[1] For more detailed comparisons see writer's paper (*loc. cit.*, pp. 43 and 44), and the discussion preceding.

types of the same species, and too often the habits of one species have been confused with those of another of the same genus, or even family, a mistake most frequently made with the Succineas. Again, the versatility of certain species—their adaptability to varying conditions—has been overlooked. *Zonitoides minusculus*, *Bifidaria pentodon*, *B. contracta*, *Succineaavara*, *S. obliqua*, etc., frequently occur in low places and then often in great numbers—but they are also found scattered over comparatively dry hillsides at considerable altitudes—and some of these species in such places develop the depauperate type, that is they average smaller in size. To show the preponderance of strictly terrestrial forms in the loess, the writer calls attention to the fact that in the collections made last June at Natchez and Vicksburg, Miss., numbering over forty species and nearly five thousand specimens, there is not a single aquatic form. Furthermore, every species which was collected in the loess of that region has been found by the writer, living upon the high bluffs and hills in and near Natchez, or upon hillsides at considerable elevations in other parts of the south, notably in northern Alabama, Georgia, and Tennessee.[1] At Natchez the most common living species is *Suecinea grosvenorii*, and this crept upon the bare surface of the loess clay which, at the time of the writer's visit, had been baked by the hot summer sun of the south during a period of drouth lasting more than six weeks. Moreover, several scores of specimens which had been carried about in the sun all day long in a box containing loess dust, and hence were subjected to extremely desiccating conditions, were found, after this experience, creeping about in their prison seemingly perfectly contented. Yet we are sometimes told that the Succineas are all "semi-aquatic," or that they must have an abundance of moisture. Another illustration, equally striking, is furnished by the writer's experiences and observations at Council

[1] It is also a significant fact that of all the living species found in the hills and bluffs of Natchez, only two, *Leucocheila fallax*, and *Polygyra texana*, were not found in the loess of that region. Only one specimen of the first and two of the second were collected. The former is not uncommon in the loess of the north, while the latter is not known from the loess, at least to the writer.

Bluffs during the past summer and autumn. It had been purposed to make a detailed comparative study of the fossil and modern molluscan faunas of that vicinity, but the work was somewhat interrupted by the severe September rainstorms and November blizzards. Nevertheless interesting and valuable data were obtained, and are here briefly presented.

More than four thousand fossils were collected, and their distribution was carefully noted in twenty exposures, beginning at the eastern extremity of 15th avenue in Council Bluffs, thence along the bluffs to the High School, a distance of about one mile, and in Fairmount Park, along its winding roads, for about half a mile eastward. The location of the several exposures is shown on the accompanying map. A list of the fossil species, together with the number of specimens collected in each exposure, is given in the appended table. If this table is studied it will be observed that of the thirty species collected not one is aquatic. For purposes of comparison the writer made collections of recent shells in seven distinct localities in practically the region containing the above-noted exposures. These localities are here discussed in detail, the letters designating them being also employed to mark them on the map.

a. A grassy, treeless hillside in Fairmount Park nearly opposite 11th avenue, and at an altitude of from 175 to 245 feet above the river valley.[1] Species 8, 11, and 29[2] were found living.

b. A grassy, treeless slope just above the exposure marked *N*. Altitude about 200 feet. Species 8, 10, 11, 15, and 29 were found.

c. Near the 10th avenue entrance to Fairmount Park, at an altitude of about 90 feet above the river plain, species 8, 10, 11, 21, 22, 27, and 30 were found. A few stunted and scattered bur oaks grow on the slope immediately above this point.

d. A brush-covered hill just above the exposure marked *E*.

[1] The altitudes were all determined by barometric measurements taken from the nearest north and south street on the river flat.

[2] The numbers refer to the species named in the table of fossils.

Altitude about 170 feet. A small collection containing species 11 and 30 was made.

e. A locality in the northwestern part of Fairmount Park on a northerly slope, somewhat grassy, but with shrubs and a few bur oaks, nearly opposite 8th avenue. Altitude 280 to 300 feet above the valley. Here were found species 3, 8, 11, 13, 18, 19, and 27, and also one specimen of *Bifidaria procera*, the only recent species found in the tract examined, which was not found in the loess. This locality is just over the brow, on the north or leeward side,[1] of one of the most exposed ridges in the area under consideration.

f. A part of the same slope immediately below *e*, and 50 to 100 feet lower. Here the forest is better developed and contains a number of species of trees. Species 8, 11, 18, 19, 22, 25, and 28 were found. The points *e* and *f* are on the same very steep slope, but *e* is much more exposed and drier, *f* being more protected by its forest covering and position. A comparison of the species from these points is therefore interesting. Species 3 and 13, while common at *e* were not found at *f*, the lower point. . While 18 was common at *e*, only one specimen was found at *f*. No. 19 is also more common at *e* than at *f*. These facts are of interest when we seek to determine the extent to which shells are likely to be washed down even very steep slopes. Nos. 8 and 11 were about equally abundant, while Nos. 22, 25, and 28 were found only at *f*.

g. The banks and grassy slope near and above the exposure *M*. This yielded species 3, 13, 21, 24, and 27.

It will be observed that species 1, 2, 4, 5, 6, 7, 9, 12, 14, 15, 16, 17, 20, 23, and 26—or just one half the total number—are not contained in the collections of modern shells cited. The number of individuals of the surface species is also comparatively small. Of these numbers, 1, 16, and 23 are extinct in that section of the country, No. 1 occurring eastward, No. 16 westward, and No. 23 being entirely extinct.

[1] The prevailing winds during the seasons of the year when the snails are active, are from the southwest.

The modern fauna of the more or less exposed hills at Council Bluffs is much poorer in species and in specimens than the fossil fauna of the underlying loess, but every species thus far discovered in the loess of Council Bluffs occurs more or less abundantly (certainly as abundantly in some places as in any part of that loess) living along the Missouri River, especially on the western, more heavily timbered bluffs. All the species above mentioned as not found in the surface collections have been collected, by the writer, on the banks and hills along the Missouri between Omaha, Neb., and Hamburg, Iowa, usually not in very damp places, but living under the conditions which prevail along those bluffs. Even *Polygyra multilineata* is there often found on high grounds, and then appears as a stunted form like that which is common in the loess.

The loess fauna of Council Bluffs is thus not only wholly terrestrial, but, with the exceptions noted, is almost identical with the modern upland fauna of the same region — and surely no conditions of excessive moisture prevail in that region today. Yet a recent writer,[1] referring to the loess of the Missouri region, says: "In the Bluff loess more than nine tenths of the total number of individuals belong to species that are found only in unusually damp situations. . . . . The species having an optimum habitat that is not excessively moist have not been observed to occur abundantly in the Bluff loess."

Another interesting fact noticeable in the exposures of loess at Council Bluffs is the occurrence of the great majority of the fossils in a more or less distinct stratum which varies (so far as observed) in altitude from about 80 to at least 200 feet above the river valley, and which follows in general the contours of the present surface, but with a less convex curvature. In exposure *N* it seems to be a continuation of the shell-bearing layer in *E*, yet it is at least 100 feet higher. In exposure *M* it drops about 80 feet in a block. Its limits are not sharply defined above or below, and it varies in thickness from about 6 to at least 20 feet. Overlying it is a deposit of more or less

[1] C. R. KEYES, Am. Jour. of Science, Vol. VI, p. 304.

laminated loess clay, which is usually non-fossiliferous, and which varies from a few to more than 30 feet in thickness. When fossils occur in this upper stratum they are few in number and widely scattered.[1]

The presence of this shell-bearing stratum suggests that, for the period during which it formed the surface soil, and while it was slowly accumulating, the conditions in this particular locality were more favorable to the growth of land snails than now. There was probably more vegetation, and hence the surface was not so frequently storm-swept as at present. This does not necessarily signify that general climatic conditions were different, but that these particular banks or bluffs were more heavily timbered, with the Missouri River probably flowing at its base, its surface conditions being similar to those of many timbered hills and knolls between Omaha and Nebraska City west of the Missouri.

It is interesting to note that between Iowa and Nebraska the Missouri River now flows along the western side of its broad valley, and that the adjacent western bluffs are more heavily timbered and contain all the living species of molluscs herein recorded, with the exception of Nos. 1 and 16, while the more remote eastern bluffs are more barren and rugged. The shell-bearing band may simply represent the period during which the river in its shiftings occupied the eastern part of the valley.

The foregoing facts lend support to the æolian theory of the origin of the loess, as is shown by the following considerations.

1. The general manner of distribution of the modern and fossil molluscs is essentially the same, this fact indicating that they were not carried by waters, but were quietly buried in dust. Had they formed a part of river drift they would be more frequently heaped together, not scattered as we find them in the loess, and fluviatile shells would be more or less intermingled.

[1] At the base of the bluff, in exposure *K*, what seemed to be a second shell-bearing layer was observed about 75 feet below the main fossiliferous band. The section, however, was more or less obscured, and the mass may have slipped from the bluff above. The fossils in column *K* in the table are from this stratum. It will be observed that they are ordinary forms which are abundant in the main shell stratum.

Moreover in many years' experience in dredging in ponds and streams, the writer has seldom seen a land shell which had been carried with the finest sediment into ponds or lakes, though such shells are sometimes found in sand and other coarse material. Currents of water which could carry most of the shells now found fossil, would also carry coarser material than that which makes up the loess. Another fact which bears out this conclusion is the presence of opercula in fossil shells of *Helicina occulta* in the northern loess and *Helicina orbiculta* in the southern loess. As the operculum so readily falls from the decaying animal, it would scarcely remain in place if the shell had been transported any distance.

2. The occurrence of fossiliferous loess chiefly in the vicinity of streams is consistent with the theory of loess formation presented by the writer before the Iowa Academy of Science.[1] Plants, and especially forests, develop chiefly and primarily along streams. This creates conditions favorable to land molluscs, and at the same time forms a trap for the dust carried from adjacent more barren regions. The occurrence of loess in the eastern part of Iowa chiefly along the border of the Iowan drift sheet may also be explained on the same ground. After the melting of the ice the terminal moraines offered the first lodging place for plants. Here forests early developed, and the conditions for entrapping the dust from adjacent less favored territory which was probably dry during a part of the year were here first created. We are in the habit of describing the lobed ridges of loess regions as characteristic of loess topography, yet they are quite as much characteristic of some drift areas, as for example, along the Big Sioux River in Iowa and South Dakota. In eastern Iowa the surface of the loess is largely shaped by the underlying moraines which first presented conditions suitable to the deposition of the loess, and where consequently the deposit is best developed. The loess at Natchez does not show this loess topography in the same degree.

3. The depauperation of some forms of shells, and the pres-

[1] Proc. Iowa Acad. Sci., Vol. III, p. 82 *et seq.*

ence of others which are normally inhabitants of dry regions, suggest a climate sufficiently dry that during a part of the year at least, clouds of dust could be taken up by the winds.

4. The overwhelming preponderance of land snails in the loess must always be borne in mind. This however does not prove that the loess regions were entirely devoid of lakes and streams, but rather that the loess proper was deposited chiefly upon higher grounds, for, if by any agency fine material were to be uniformly deposited over all of Iowa today, covering the successive generations of our present molluscan fauna, there would be a much greater proportion of aquatic and moisture-loving species than we find anywhere in the loess.

5. The amount of material carried by the winds need not have been so great as is sometimes assumed. The estimate made by the writer[1] for the rate of deposition for eastern loess (1 mm per year), and that made by Keyes[2] for western loess ($\frac{1}{10}$ to $\frac{1}{4}$ of an inch), would be sufficient to form most of these deposits respectively in the 8000 years, usually computed, since the recession of the glaciers.

The objection made by Dr. Chamberlin[3] that "the æolian deposits are measured, not by the quantity of silt borne by the winds and lodged on the surface, but by the difference between such lodgment and the erosion of the surface," is met, at least in part, by the theory offered, for it is a well-known fact that timbered areas, even when very rough and with abrupt slopes, are scarcely eroded by even the most violent precipitation of moisture. Professor Udden's recent admirable report[4] also bears on this question, and should not be overlooked by the student of loess problems.

6. No distinction can be made between the origin of eastern and western loess. The finer quality and lesser thickness of the former rather suggest that there had been more moisture (*i. e.*,

[1] Proc. Iowa Acad. Sci., Vol. III, p. 88.

[2] Am. Jour. of Sci., Vol. VI, pp. 301, 302.

[3] Jour. Geol., Vol. V, p. 801.

[4] The Mechanical Composition of Wind Deposits, 1898.

a shorter dry period during each year), and hence less dust; that the winds were less violent, and that there were greater areas completely covered with vegetation, this resulting in the necessity of transporting dust much greater distances, which would therefore be finer.[1]

It should be borne in mind that the above-noted differences between the regions in question actually exist today. There is more rain, there are larger areas closely covered with vegetation, and less violent winds prevail, in eastern Iowa, and eastward, and considering the position of mountain chains and seas, the same differences must have existed for a long time. That they did exist during the deposition of the loess is also indicated by the proportionately somewhat larger number of species in the eastern loess, which prefer or require moist habitats. But the fauna of the eastern, or Mississippi River loess is essentially a terrestrial fauna. The great fluviatile groups now everywhere common in the streams of eastern Iowa are wanting in the loess, and the few fossil aquatic species are such as today prefer ponds, and are often found even in those which dry up during the summer.

It may again be emphasized that the fossils show no greater difference between the surface conditions which existed during the deposition of the loess of the eastern and the western parts of Iowa, than exists today between the surface conditions of the same regions. This fact is irrefutable, and must not be overlooked in any discussion of the conditions under which loess was deposited.

NOTES AND EXPLANATION OF MAP

[Scale, 8 in. to 1 mile]

The exposures are represented by heavy lines.

EXPOSURES *A*, *B*, and *C*

These were cut out of the same ridge in street grading. The shell-bearing stratum shows well on the east, south and west sides of *C*. It is about 12–15 feet thick. Above it there is a layer of clay about fifty feet thick and almost entirely devoid of fossils.

[1] See UDDEN, *loc. cit.*, pp. 56, 57 and 67.

TABLE OF SPECIES[1]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1. *Helicina occulta* Say	5	55	210	5	5	81	17	89	9	14	3	12	14	96				1		
2. *Vallonia gracilicosta* Reinh.	10	157	12		1	8		21		3	1	1	1	45	1				1	
3. " *parvula* Sterki	2																			
4. " *perspectiva* Sterki	3	12																		
5. *Polygyra multilineata* (Say) Pils.		6	70	2		16	4	7		6	1		2	3	1		2		1	1
6. " *profunda*[2] (Say) Pils.																				
7. " *hirsuta*[3] (Say) Pils.	1																			
8. " *leai* (Ward) Pils.	4	21	63	1	1	17	2	14		4			1	12			2			
9. *Strobilops virgo* Pils.	8		3			2		1	1					1						
10. *Leucocheila fallax* (Say) Try		2																		
11. *Bifidaria armifera* (Say) St.	35	280						3	1											
12. " *contracta* (Say) St.	5																			
13. " *holzingeri* (St.) St.								1												
14. " *curvidens* (Gld.) St.	1											2	4	12			2	3	2	
15. " *pentodon* (Say) St.																				
16. *Pupa blandi* (Morse) Binn.	11	127			1							10	3	28						
17. *Vertigo bollesiana* Morse																				
18. *Cochlicopa lubrica* (Müll.) P. & J.	1	4	27	1	1	12		22	1	2				18						
19. *Vitrea hammonis* (Ström.) P. & J.	2	3	10			10	1	3			1	1		1						
20. " *indentata* (Say) P. & J.			1																	
21. *Conulus fulvus* (Drap.) Müll.						1		1	1				1	5						
22. *Zonitoides arboreus* (Say) St.	3	4	21			4	2	12						10			3			
23. " *skinneri*[4] (Pils.) P. & J.															2		1		2	
24. " *minusculus* (Binn.) P. & J.	1	2	6			1		3			1			7						
25. *Pyramidula alternata* (Say) Pils.		4	19		1	4	1	11	3	2				1						
26. " *striatella* (Anth.) Pils.	1	20	46	3		21		28	2		1	4	4	24	2			3	1	
27. *Helicodiscus lineatus* (Say) Morse	6	18	6		1	7		5						13						1
28. *Succinea obliqua*[5] Say 29. " *grosvenorii* Lea	3	180	935	8	10	235	58	279	8	72	21	12	5	250	4	2	15	3	15	3
30. " *avara* Say	15	11	16			7	1	11		2	1	3	2	14	4	2		3	5	
31. Egg of a land snail						1										1				

EXPOSURE *D*

The shell stratum is not so rich in fossils as in *C*. Above it there are 15–20 feet of clay in which a few Succineas were found. In the clay below the shell stratum there are several distinct but irregular bands of lime nodules — some very large.

EXPOSURE *E*

Very similar to *D*, but with only one band of nodules.

EXPOSURE *F*

Fossils are very abundant in the shell stratum, which can here be traced for 3 or 4 rods. The shell-less loess above is 8 or 10 feet thick.

EXPOSURES *G*, *H*, *I*, *J*, and *K*

These exposures were all formed from the same ridge by deep cutting and grading. The shell stratum is distinct in all of them, and, as in all the other sections, it follows in general the contour of the surface. It varies in thickness here from 6 to 20 feet. It is by no means equally fossiliferous throughout.

EXPOSURES *L* and *M*

These were formed by the grading of High School avenue. The street slopes westward from the High School, and drops about 60 feet in a block.

[1] The nomenclature of Pilsbry and Johnson's recent *Catalogue of the Land Shells of North America* is here employed. As there are some departures from former usage, the changes are here noted:

Species 2, 3, and 4 were formerly included under *V. pulchello*.

Species 5 and 6 were referred to the genus *Mesodon*, and 7 and 8 to *Stenotrema*.

Species 9 was included under *Strobila labyrinthica*.

The species of *Leuchochila* and *Bifidaria* were included in *Pupa*.

Species 18 was called *Ferussacia subcylindrica*.

Vitrea, *Comulus*, and *Zonitoides* were formerly placed in the genus *Zonites*, and No. 19 was called *Zonites radiatulus*.

Pyramidula was formerly *Patula*.

Species 29 was called *S. lineata*.

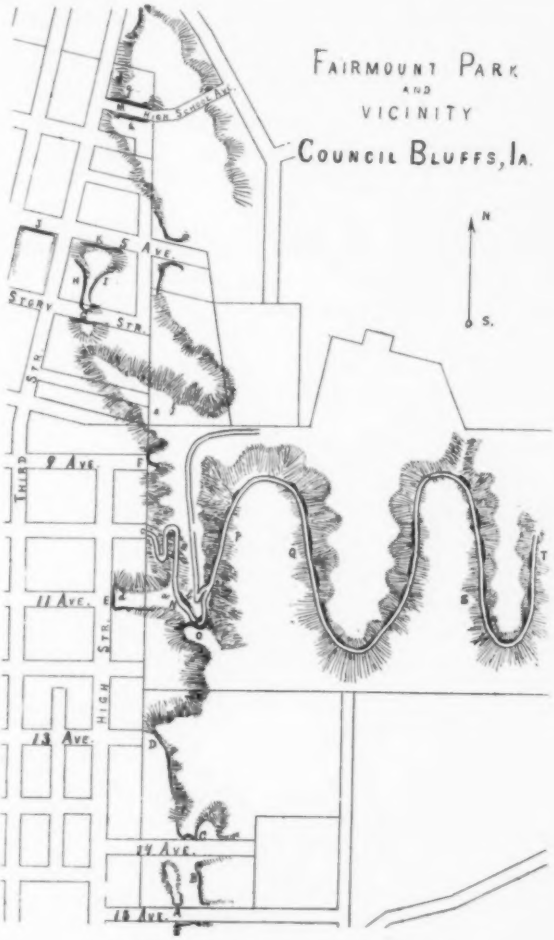
[2] One specimen of *P. profunda* was found by the writer in exposure C (since considerably altered) in 1890.

[3] Three specimens of this species were collected in exposure C in 1890.

[4] The writer formerly regarded this as a form of *Zon. nitidus*. Mr. Pilsbry, however, regards it as distinct, and in deference to his opinion his name is retained.

[5] The form of *S. obliqua* which occurs most commonly in the loess is the narrower, smaller form, with more extended spire, such as is not uncommon (living) in Iowa and as far east as Indiana. As it is difficult to distinguish between some forms of this and *S. grosvenorii*, the two species are not here separated, as more time for careful comparison of the large sets will be required.

On the north side the shell stratum is nearly parallel to the street grade, and but little above it. On the south side it dips below the street about half way down the slope.



EXPOSURES *N*, *O*, *P*, *Q*, *R*, *S*, and *T*

These are all exposures along the road which winds eastward from the 10th avenue entrance to Fairmount Park. At *N* the road is about 185

feet above the river valley, and the shell stratum (which is here very rich in fossils) extends about 3 feet higher. It dips down toward the west at such an angle that it would connect with the shell stratum at *E*, which is about 100 feet lower. The same layer may be traced more or less indistinctly to *O*, where there is a cut about 20 feet deep. The shell stratum rises to about 8 feet above the roadbed (here about 200 feet above the river valley), but fossils are not abundant. The remaining exposures along this road are formed by the road cutting the smaller, lateral lobes of the greater ridges. The letters apply to the extent of road from bend to bend, not to individual exposures. At the southern bends in the road are the high points, the road sloping down to near the bases of the ridges to the north.

Fossils are found in most of the little exposures (which in but few cases exceed 15 feet in height) along the road, but they are nowhere as abundant as in some of the exposures along the bluff fronts. The exposures which are represented on the map, but not lettered, are nonfossiliferous.

B. SHIMEK.

THE GRANITIC ROCKS OF THE SIERRA NEVADA[1]

THE higher part of the central Sierra Nevada and nearly the entire width of the southern Sierra consist of a granular complex to most of which the name granite is ordinarily applied. In the northern and central part of the range there are likewise numerous isolated granitic areas enclosed in rocks of other kinds. The rocks of the granular complex differ greatly in age and in chemical composition. The oldest rocks represented are gneisses. Some of these are probably recrystallized sediments, but the larger portion of them may be of igneous origin. While differing in origin these gneisses are a unit in that they have all undergone a thorough recrystallization under great pressure. While the associated granites may be in part responsible for this recrystallization it cannot be ascribed to contact metamorphism alone, for areas miles in diameter are as thoroughly crystalline in their middle portions as at the granitic contact. At a future time these gneisses will be described. Some notes regarding them may be found in the Seventeenth Annual Report of the United States Geological Survey and in the text of the Big Trees folio.

The granolites[2] of the Sierra Nevada comprise nearly the entire range of granular igneous rocks. Peridotite, pyroxenite, hornblendite, gabbro, diabase, diorite, syenite, monzonite, and granite, with various intermediate types, are all represented. In this paper, however, reference will be made only to the granitic

[1] Published by permission of the Director of the U. S. Geological Survey. A large amount of information has been accumulated about the granular complex of the Sierra Nevada. It is thought better, however, to delay the publication of this material until the field work now under way is completed. There is some confusion in regard to the biotite-granite of the range and the granodiorite and quartz-monzonite. They are, therefore, more fully treated than other types of which only a brief statement is presented here.

[2] The term granolite is here used for all granular igneous rocks; thus diorite, gabbro, syenite, and granite would all be called granolite. It was first suggested by Professor L. V. Pirsson.

rocks or acid granolites, those containing free silica or quartz as an essential constituent, that is to say, in considerable amount.

Seven types of quartz-granolites have thus far been recognized. The relative age of all of them is not definitely ascertained, but so far as known it is expressed in the order in which the different types are enumerated, as follows: biotite-granite, granodiorite, quartz-monzonite, porphyritic quartz-monzonite, Bridal Veil granite, soda-granite and aplite, potash-aplite and pegmatite.

BIOTITE-GRANITE

Biotite-granite forms very large areas in the central portion of the Sierra Nevada. It is particularly abundant in the Big Trees and Yosemite quadrangles,[1] where it has been examined most closely. The coarse biotite-granite is a rock susceptible of easy recognition in the field. Potash-feldspar is an abundant constituent, and by its conspicuous development in relatively large crystals tends to give the rock a porphyritic look. Other minerals less readily seen with the naked eye are quartz and biotite; the former in distinct grains of irregular shape, and the latter so arranged as to give a suggestion of gneissic or banded texture, even in hand specimens. Perfectly fresh specimens are secured with difficulty as the rock weathers to a considerable depth and becomes somewhat friable. Under the microscope the porphyritic texture is generally inconspicuous. The component minerals are soda-lime-feldspar (oligoclase) > quartz > potash-feldspar > biotite > titanite > apatite > zircon. The relative proportions of these minerals are deduced from a calculation as noted later. Chlorite is usually present as a decomposition product of the biotite, and secondary epidote may often be noted. Rutile-like needles were observed in some quartzes.

Biotite-granite usually weathers in yellowish tones, and in forms suggestive of bedding, due to a more or less well-developed gneissic structure. Indeed, at many points the biotite-granite has been greatly compressed and sheared, so that much

[1] As used by the U. S. Geological Survey a quadrangle is the area of country covered by a topographic sheet of the Atlas of the United States.

of it may be called biotite-granite-gneiss. Ilmenite was found in the granite-gneiss, but not in the more massive granite. As the granite-gneiss has, after shearing and compression, undergone recrystallization, the ilmenite may possibly be secondary. At some points the crushing, shearing and recrystallization has been so thorough that the original massive granite has been converted into a moderately fine-grained gneiss.

Analyses have been made of this granite collected at three different points. These analyses show but slight variation in composition. There is also given an average of these three analyses, and from this the molecular composition has been calculated. Analysis 164 is of a biotite-granite which is regarded by Lindgren[4] as representative of the biotite-granite of Pyramid

ANALYSES OF BIOTITE-GRANITE

	1452 S. N.	1485 S. N.	2136 S. N.	Average of Nos. 1452, 1485 and 2136	Molecules of average	164 Pyramid Pk.
SiO_2	70.43[1]	70.75[2]	71.08[3]	70.75	1.1792	77.68[3]
TiO_2	.24	.42	.22	.29	.0036	.14
ZrO_2	.....	.....	.08	.03	.0002	.....
Al_2O_3	15.51	15.13	15.90	15.51	.1521	11.81
Fe_2O_3	.96	.98	.62	.85	.0053	.72
FeO	1.28	1.43	1.31	1.34	.0193	.51
MnO	trace	trace	.15	.05		trace
NiO	?	none	.....	.....	.....	.....
CaO	2.76	3.09	2.60	2.82	.0532	.72
SrO	.05	.04	.02	.04		.....
BaO	.20	.12	.04	.12		.....
MgO	.37	.73	.54	.55	.0137	.18
K_2O	5.14	3.62	4.08	4.28	.0455	5.00
Na_2O	2.75	3.05	3.54	3.11	.0501	2.96
Li_2O	trace	trace	trace	trace	.....	.....
H_2O below 110° C.	.08	.10	none	.06	.....	.04
H_2O above 110° C.	.40	.51	.30	.40	.0222	.27
P_2O_5	.11	.10	.10	.10	.0007	.10
CO_2	none	none	trace	.....	.....	.....
FeS_2	trace	.06	.....	.02	.....	.....
SO_3	.....	.....	none	.....	.....	.....
Cl	.....	.....	.02	.02	.0005	.....
Total	100.28	100.13	100.60	100.34	1.5456	100.13

Analyst: [1] Hillebrand. [2] Valentine. [3] Steiger.

[4] Am. Jour. Sci., Vol. III, 1897, p. 307.

Peak quadrangle. It will be noted, however, that the description of the rock by Lindgren indicates that it approximates in texture to a granite-porphyry, and that the chemical composition is nearer that of an aplite than of the biotite-granite to the south of the Pyramid Peak district. I myself have not observed the latter to pass into porphyritic forms with a fine-grained groundmass.

The calculation of the mineral composition is made in the following way. All of the phosphorous pentoxide (P_2O_5) is ascribed to apatite. All the magnesia (MgO) is ascribed to biotite. The molecular ratio of the oxides in the biotite is calculated from an analysis of biotite separated from biotite-granite No. 2136, and as the biotite in all the biotite-granite is optically similar, it is fair to assume that it has, in all three of the granites, averaged, sensibly the same composition. After deducting the titanium oxide (TiO_2) required for the biotite, the remaining titanium oxide is ascribed to titanite. All the zirconium oxide (ZrO_2) is calculated as zircon. After deducting the potash (K_2O) in the biotite, all the remainder is calculated as in potash-feldspar. All the soda (Na_2O) in the rock is supposed to be present in the albite. The chemical analysis[1] of the biotite, however, shows that it contains a little soda (0.38). In calculating the ratio of the oxides in the biotite, the soda was placed

Composition of the biotite-granite, deduced from the average analysis above given		Pyramid Peak. 164. Lindgren
	Per cent.	Per cent.
Quartz	33.06	39.80
Potash-feldspar	20.70	28.17
Soda-feldspar	26.19	25.09
Lime feldspar	12.91	2.47
Biotite	5.64	3.10
Magnetite	.69	.61
Titanite	.55	.35
Apatite	.24	.25
Zircon	.01	.....
Water	.....	.31
	99.99	100.15

[1] Am. Jour. Sci., 1899.

with the potash. As the biotite forms only about one twentieth of the rock, the error in ignoring the soda in the biotite is small, and would not sensibly alter the result. If, however, the biotite forms a considerable part of the rock, its soda content should be separately calculated and the amount of soda in the biotite deducted from the total soda, the remainder being considered as in albite. After deducting the lime (CaO) for the apatite, titanite, and biotite, the remaining lime is calculated as in anorthite. The oxides of strontium and barium are placed with the lime. After deducting the iron-oxides (Fe_2O_3 and FeO+MnO) for the biotite, all the remaining iron oxides are calculated as in magnetite. After deducting the silica (SiO_2) for the titanite, biotite, and feldspar, all the remaining silica is calculated as quartz.

GRANODIORITE

The granitoid rocks of the Sierra Nevada that were intruded at the close of Jurassic time, may be regarded as portions of one great batholith that may be supposed to underlie the entire range. The quartz-monzonites hereafter described are not regarded as belonging to the granodiorite batholith. All of the areas of this batholith are not connected at the surface, but it is more than probable that these separated areas are merely extruded tongues or gigantic apophyses of the main mass. Viewed from this standpoint, the variation of the chemical and mineral composition of this batholith is extraordinary. The rocks range from acid quartz-diorites containing over 70 per cent. of silica through quartz-mica-diorites, quartz-hornblende-diorites and quartz-pyroxene-diorites to gabbros and even olivine-gabbros. That these different rocks may be regarded as facies of one magma, appears to be indicated by the usual absence of sharp contacts and the existence of transition forms between them. The table of analyses given below probably represents very accurately the chemical variation of the rocks of the batholith. While the authors of the Gold Belt folios have always had in mind, as the typical granodiorite, a rock intermediate between granite and

diorite, in actual use the term in some of my own folios has been applied to all the rocks of which analyses are given in the table, so far as field mapping is concerned, although as a rule gabbro, even when genetically related to granodiorite proper, has been separated. Since the term has been so extensively used for quartz-diorites containing orthoclase, it is thought better to restrict the term to this usage and to call the rocks which are strictly intermediate between granite and diorite, quartz-monzonite.

While there is some doubt as to all of the areas called granodiorite in the folios being actually all portions of one magma, yet there is so great a variation within so many of these areas that the fact that the magma is a greatly variable one is established independently of the consideration of the batholith as a whole.

The evidence that the areas ascribed to this great batholith were intruded at nearly the same time is not altogether satisfactory, but at all places it points in the same direction. That is to say, wherever the granolites composing the batholith come into contact with other rocks, excepting those of post-Jurassic age, it is usually evident that they have metamorphosed those rocks, indicating that they are intrusive in them and are of later age. West of Mariposa the granodiorite has cut off and metamorphosed the Jurassic Mariposa slates into chiastolite- and mica-schists. At Mineral King, in the heart of the Sierra Nevada, to the west of Mt. Whitney, is a lens of Juratrias sediments which has been metamorphosed by granodiorite. The evidence is good that the great bulk of the pyroclastic meta-augite-andesites of the foothills are of Juratrias age. That the granodiorite is intrusive in these rocks at some points, and has metamorphosed them, is evident in the field, as for example, north and east of Mormon Bar in Mariposa county, where the meta-augite-andesite-tuffs have undergone a thorough recrystallization. In Plumas county, southeast of Sierra City, the Juratrias rocks of the Milton formation have likewise been

metamorphosed by granodiorite; also north of Genesee Valley[1] there is a quartz-gabbro which is a basic facies of the great batholith, and the adjoining Triassic slates have been metamorphosed into hornfels. There is also evidence that the rocks of this batholith are later in age than the serpentines and associated magnesian rocks. This is particularly evident in the Bidwell Bar quadrangle, where the rocks of the magnesian series are cut by dikes of granodiorite, and in general throughout this quadrangle the rocks surrounding the granodiorite areas, whether of sedimentary or of igneous origin, show contact metamorphism. However, in the Bidwell Bar quadrangle the age of the sedimentary rocks, so far as known, is Carboniferous, and it can therefore only be said that in this region the granodiorite is post-Carboniferous.

In a paper[2] published in 1893, Lindgren describes typical granodiorite as follows: "The rock consists in typical development of feldspar, quartz, biotite, and hornblende with medium-grained hypidiomorphic structure. The soda-lime-feldspars are usually considerably and to a variable extent in excess of the alkali-feldspars. The silica varies between 60 and 73 per cent.; the amount of lime is variable, but it rarely exceeds, while it usually falls somewhat short of, the sum of the alkalies. While in some varieties which cannot be distinguished from the others in the field, there is more potash than soda, a frequently occurring relation is 2 per cent. Ka_2O to 4 per cent. Na_2O. It will be seen that the rock very closely approaches some quartz-mica-diorites and often might be indicated by that name."

In his later paper on the gold quartz veins of Nevada City and Grass Valley, published in the Seventeenth Annual Report of the U. S. Geological Survey, Lindgren gives the limits of chemical variation and average composition of granodiorite as follows.

[1] DILLER, Bull. 150 U. S. Geol. Surv., p. 338.

[2] The Auriferous Veins of Meadow Lake, California. Am. Jour. Sci., Vol. XLVI, 1893, pp. 202, 203.

In his investigation of Pyramid Peak quadrangle, Lindgren found large areas of granitic rocks containing amphibole and biotite and resembling granodiorite in a general way. Some of these rocks are somewhat basic and probably correspond to the granodiorite of the Gold Belt region in chemical composition; but other areas contain more alkali and less lime than the typical granodiorite of this paper. Lindgren, however, concluded that this alkali-rich rock should be called the typical granodiorite, inasmuch as it occurs in very large areas, and also since it occupies a place almost exactly intermediate between quartz-diorite and granite. Since that time much field work has been done in the south central Sierra Nevada where the granular complex is finely exposed, most of the soil and loose rock having been removed by the glaciers that formerly covered the region. The opportunities, therefore, of studying the relations of the granites in this section are unexcelled. The different granitic rocks resemble one another so much in general aspect that the contacts between different kinds are sometimes discovered only after careful search. As a rule a person will pass from one kind of granite to another without having observed any change in the rock until the difference is called to his attention by some striking feature. It is not to be wondered

LIMITS OF VARIATION AND AVERAGE COMPOSITION OF GRANODIORITE

	Limits of variation	Average composition
	Per cent.	Per cent.
SiO_2	50 to 68½	65
Al_2O_3	14 to 17	16
Fe_2O_3	1½ to 2¼	1.50
FeO	1½ to 4½	3
CaO	3 to 6½	5
MgO	1 to 2½[1]	2
K_2O	1[2] to 3½	2.25
Na_2O	2½ to 4½	3.50
Remainder	.....	1.75
		100

[1] Three and one half in one analysis.

[2] Certain masses in the foothills go below 1 per cent.

at, therefore, that the relations of the different granites is not yet clearly understood. The exposures at a number of points clearly show that the granodiorite proper is intrusive in, and therefore younger than, the biotite-granite. Other exposures near Yosemite Valley show a sharp contact between the rock here called quartz-monzonite and granodiorite proper. While the evidence of these two rocks being distinct is not altogether satisfactory at present, it is probable that the quartz-monzonite is later in age than the granodiorite. In order to show the chemical relations of granodiorite to related rocks, some partial analyses are here given:

		Granodiorite series		Quartz-monzonite		103 Pyramid Peak
	Tonalite	Quartz-diorite	Granodiorite	Banatite	Adamellite	
Silica	66.91	57.74	65.48	64.39	68.39	67.45
Alumina	15.20	17.36	16.05	15.90	13.47	15.51
Lime	3.73	6.81	4.88	4.15	3.24	3.60
Magnesia	2.35	3.62	2.13	1.93	1.02	1.10
Potash	.86	2.01	2.43	3.57	3.28	3.66
Soda	3.33	3.07	3.49	3.48	3.85	3.47

The rock described by vom Rath and called tonalite, has sometimes been regarded as a synonym for granodiorite. That such is not the case, however, will appear from the analysis given above. If this analysis is reliable it is clear that tonalite is a typical quartz-diorite unusually rich in silica. The analysis of the tonalite is the mean of two analyses by Kenngott.[1] The specimen analyzed came from Avio See and vom Rath,[2] who originated the name, analyzed the plagioclase of the tonalite of Adamello, and found the feldspar to be basic andesine

The quartz-diorite analysis may be regarded as a fair average of the smaller granodiorite areas noted in the Gold Belt folios and of the marginal portions of larger areas. This analysis is the mean of five basic quartz-diorite analyses given in the large table of granodiorite analyses.

[1] Zeit. Geol. Ges., Vol. XVII, 1865, p. 572.

[2] Zeit. Geol. Ges., Vol. XVI, 1864, p. 249.

ANALYSES OF ROCKS FROM THE POST-JURASSIC GRANODIORITE BATHOLITH OF THE SIERRA NEVADA

	Olivine gabbro	Basic quartz-diorites					Granodiorites proper					Acid quartz-diorites	
	No. 941 S. N.[1]	No. 1495 S. N.[2]	No. 225 S. N.[2]	No. 936 S. N.[2]	No. 851 S. N.[3]	No. 691 S. N.[1]	No. 369 S. N.[2]	No. 17 S. N.[2]	Grass Valley[2]	Nevada City[2]	No. 71 S. N.[2]	No. 303 S. N.[2]	No. 22 S. N.[2]
SiO_2	43.41	55.86	57.26	57.80	58.09	59.68	62.62	63.43	63.85	66.65	67.33	68.65	70.36
TiO_2	.39	1.20	.53	.70	.95	.65	.55	.73	.58	.38	.36	.28	.20
Al_2O_3	23.15	19.30	16.51	16.43	17.46	17.09	17.51	14.20	15.84	16.15	15.93	16.34	15.47
Cr_2O_3	none	....	none	none	....	none	....	....	....	....	....	....	....
Fe_2O_3	3.72	.91	3.27	1.62	1.12	2.85	.49	1.54	1.91	1.52	1.90	.93	.98
FeO	4.39	4.78	5.19	6.51	5.08	2.75	4.06	4.56	2.75	2.36	1.59	1.48	1.17
MnO	.08	.16	.18	.18	none	trace	.05	.03	.07	.10	.09	.08	trace
NiO	none	trace	trace?	.03	....	none	....	....	....	....	....	....	....
CaO	14.27	7.31	6.69	7.21	6.24	6.62	5.49	5.51	4.76	4.53	4.09	3.07	3.18
SrO	none	.04	.06	trace?	.04	trace	trace	trace	trace	trace	trace	.07	trace
BaO	none	.13	.10	.09	.07	.04	trace	.06	.06	.07	.08	.09	.06
MgO	7.65	2.94	3.41	4.14	4.06	3.54	2.84	2.35	2.07	1.74	1.63	1.29	.87
K_2O	.22	1.52	2.93	2.29	2.02	1.31	1.76	2.19	3.08	2.65	2.46	1.85	1.71
Na_2O	.82	3.52	2.65	2.35	2.94	3.87	3.49	3.49	3.29	3.40	3.76	4.85	4.91
Li_2O	trace	trace	trace	trace	none	trace	trace	none	trace	trace	trace	trace	trace
H_2O below 110° C	.18	.19	.20	.11	.29	.15	.22	.15	.28	.18	.19	.24	.06
H_2O above 110° C	1.53	1.23	.95	.38	1.45	1.00	.92	1.50	1.65	.72	.66	.62	1.00
P_2O_5	.02	.38	.30	.19	.17	.25	.12	.11	.13	.10	.11	.15	.11
CO_2	.10	none	none	none	.21	.20	....	....	....	....	....	....	....
FeS_2	.14	.39	none	none	c. .11	none	....	....	.04	.02	....	....	....
SO_3	....	....	....	....	.05	trace	....	....	....	....	....	....	....
Cl	trace	....	....	....	.02	.03	....	....	....	....	....	....	....
F	....	....	....	....	trace	none	....	....	....	....	....	....	....
Total	100.09	99.86	100.23	100.03	100.37	100.03	100.12	99.85	100.36	100.57	100.18	99.99	100.08

Analyst: [1] Stokes, [2] Hillebrand, [3] Steiger.

The granodiorite analysis may be regarded as typical of that rock and as representing the average rock of many areas. The analysis is the mean of the five analyses given in the large table. A comparison with the banatite analysis indicates a close relationship, but a granodiorite very seldom attains so high an alkali content as that of a banatite. The banatite analysis is a mean of five analyses by Brögger.[1] The analysis of the adamellite is a mean of six analyses by Brögger.[2] The quartz-monzonite analysis 103 Pyramid Peak is Lindgren's typical granodiorite of his latest paper.[3] It is clear that this rock would be placed with the monzonites by Brögger.

Granodiorite when typical is composed of plagioclase (oligoclase-andesine, but usually andesine) > quartz > orthoclase. Biotite and green aluminous amphibole are abundant constituents, but are variable in their relative amounts, and at times only one of these ferro-magnesian elements is present. Magnetite, titanite, and apatite are nearly always present as accessories. The rock is usually evenly granular in texture and of a light gray color.

QUARTZ-MONZONITE

As has already been stated under granodiorite, there are very large areas of a rock containing amphibole and biotite which resembles granodiorite and perhaps may be related to it genetically. From the analyses given below it will be seen, however, that the rock is richer in alkali and poorer in lime than the most acid of the granodiorites of the Gold Belt. This rock forms part of the east wall of Yosemite Valley and Half Dome, North Dome, Starr King, and other points. In general it is quite massive and thus lends itself to a method of weathering called exfoliation, which ordinarily results in the production of dome-like forms. It is composed of oligoclase > quartz > orthoclase > biotite > amphibole. There are present as accessories titanite, apatite, iron ore, and zircon. It thus strongly resembles grano-

[1] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo, p. 62.

[2] *Ibid.*, p. 62.

[3] Am. Jour. Sci., 1897.

	Quartz-monzonite			Porphyritic quartz-monzonite	Soda-granite and aplite			Quartz-diorite aplite	Quartz-diorite
	No. 2179 S. N.	No. 1751 S. N.	No. 103 Pyramid Peak	No. 39 S. N.	No. 399 S. N.	No. 413 S. N	No. 725 S. N.	No. 1490 S. N.	No. 1495 S. N.
SiO_2	66.83	66.91	67.45	66.28	73.18	74.21	76.00	69.66	55.86
TiO_2	.54	.....	.58	.54	.25	.30	.04	.21	1.20
ZrO_2	.04	.....	.....	.....	.....	.....	.....	.....	.....
Al_2O_3	15.24	.....	15.51	16.03	13.66	14.47	14.88	17.57	19.30
V_2O_3	.....	.01[1]	.....	.....	.....	.....	.....	.....	.....
Fe_2O_3	2.73	.....	1.76	1.80	.21	.35	.65	.21	.91
FeO	1.66	.....	2.21	1.88	2.24	.50	.10	1.04	4.78
MnO	.10	.....	.....	.05	.07	none	trace	trace	.16
NiO	.....	.....	.....	.....	.....	.....	none	none	trace
CaO	3.59	3.51	3.60	3.75	2.10	1.71	.19	4.54	7.31
SrO	.03	.....	.....	trace	trace	trace	none	.05	.04
BaO	.11	.....	.....	.08	.10	none	trace	.03	.13
MgO	1.63	.....	1.10	1.12	.93	.28	.06	.58	2.94
K_2O	4.46	3.13	3.66	3.49	2.72	.10	2.77	.71	1.52
Na_2O	3.10	3.59	3.47	4.10	3.70	7.62	3.52	4.91	3.52
Li_2O	trace	trace	.....	trace	trace	trace	none	none	trace
H_2O below 110° C.	none	.....	.14	.11	.10	.15	.20	.05	.19
H_2O above 110° C.	.56	.....	.63	.39	.57	.23	1.42	.50	1.23
P_2O_5	.18	.....	.12	.30	.09	.07	.11	.03	.38
CO_2	trace	.....	.....	.....	.17	.....	none	none	none
FeS_2	.....	.....	.....	.....	.....	.....	.....	trace	.39
SO_3	none	.....	.....	.....	.....	.....	.....	.....	.....
Cl	.02	.....	.....	.....	.....	.....	.....	.....	.....
F	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	100.82	.....	100.25	99.92	100.09	99.99	99.94	100.09	99.86
Analyst	Valentine	Stokes	Steiger	Hillebrand	Hillebrand	Hillebrand	Stokes	Hillebrand S = trace	Hillebrand S = 0.21

[1] The V_2O_3 det. by Hillebrand.

diorite in mineral composition. One of the chief differences is the more acid character of the plagioclase which is, so far as known, always oligoclase. It also contains zircon, which is not usually found, and certainly is not abundant, in granodiorite. It is probably, moreover, of later age. The quartz-monzonite of the Sierra Nevada would be called a hornblende-biotite-granite by Rosenbusch. The three analyses given in the table below indicate that the chemical composition of this rock is remarkably uniform. The quartz-monzonite of the east wall of Yosemite Valley appears to be in sharp contact with the granodiorite mass that lies immediately west. At any rate the transition from the even-grained monzonite with scattered amphiboles to the more basic granodiorite, occurs within a very few feet at a number of points. More investigation, however, is needed.

The adoption of the term quartz-monzonite instead of granodiorite will perhaps be objected to by some petrographers on the ground that granodiorite is the older term. As has been shown, however, the latter rock does not occupy a strictly intermediate position between granite and quartz-diorite unless we extend the range of its chemical variation so as to include the quartz-monzonite of the higher parts of the Sierra. If we should confine the term quartz-monzonite, or granite-diorite, to quartz-feldspar rocks in which the potash and soda-lime feldspar are present in about equal amount, as Brögger has done, we would then have to exclude from this type nearly all of the rocks called granodiorite (quartz-orthoclase-diorite) in the Gold Belt folios. It would, therefore, seem better to let the term granodiorite stand for the rocks for which it has been used, and use one of the perfectly definite terms quartz-monzonite or granite-diorite for the rocks intermediate between granite and quartz-diorite. The term monzonite has already been adopted by the United States Geological Survey for folio use, and it seems, therefore, desirable for the members of the survey likewise to use the term quartz-monzonite for monzonites containing abundant quartz, in the same way that we use quartz-diorite for diorites containing abundant quartz.

THE PORPHYRITIC QUARTZ-MONZONITE[1]

Forming large areas along the higher parts of the range is a coarse granitic rock containing numerous porphyritic orthoclases which are often more than two inches in length. This rock is in sharp contact with the quartz-monzonite, above described, to the northwest of Lake Tenaya in the Yosemite Park, and doubtless at other points. While not differing much in chemical composition (see No. 39, table of analyses) from the latter rock, its marked porphyritic character and the usual absence of amphibole readily distinguish it. Along the contact, however, the porphyritic quartz-monzonite sometimes contains abundant amphibole. The orthoclase phenocrysts are evidently formed at a late period in the consolidation of the rock, for these contain as inclusions most of the minerals of the groundmass, including plagioclase, biotite, quartz, titanite, and iron oxide. The inclusions have no definite arrangement in the phenocrysts.

BRIDAL VEIL GRANITE

In the drainage of Bridal Veil Creek, on Horse Ridge, and at many other points in the Yosemite Park, there are considerable masses of a white, rather fine-grained granite which has been designated Bridal Veil granite. It often shows an orbicular structure, there being a central white nucleus composed of quartz and feldspar, surrounded by a layer rich in biotite. This granite is intrusive in the biotite granite and often contains near the contact chunks of the latter. It also incloses fragments of dioritic rocks, which are likewise found as nodules and small areas in

ANALYSES OF BRIDAL VEIL GRANITE

	No. 2558 S. N.	No. 2051 S. N.
SiO_2	71.45	69.81
CaO	2.40	2.31
K_2O	3.25	5.25
N_2O	3.53	2.79

[1] Fourteenth Ann. Rep. U. S. Geol. Surv., pp. 478–480.

some of the other granites. No complete analysis has been made of this granite, but there are given above two partial analyses which indicate some variation in chemical composition if they are in reality both from the same magma.

No. 2558 is from north Cathedral Rock in Yosemite Valley, and No. 2051 is from a dike in the bed of the Middle Tuolumne River, about 4.5 kilometers northeast of Bald Mountain. Both analyses were made by Dr. H. N. Stokes.

SODA-GRANITE AND APLITE

Granitic rocks rich in soda are not abundant in the Sierra Nevada. The largest mass known lies east of Cathay Valley in Mariposa county. This area is clearly later than the diabase that is found to the west. Along the contact in and southeast of Cathay Valley a contact-breccia has been formed which is a mile or more in width. This is composed of fragments of the diabase cemented by the soda-granite. On the northeast the aplite area is in contact with the slates of the Mariposa formation. These slates are flinty near the contact on Agua Fria Creek, where also they are of a peculiar light gray color. Microscopic examination does not show any very marked metamorphism. Near the contact, however, the granitic rock is richer in lime (analysis 399, S. N.), which it may have absorbed (?) from the slates. The rock may also be regarded as a basic contact facies due to differentiation. In either case the above facts suggest that the granite is later in age than the Jurassic Mariposa slates. No. 399 was collected on Agua Fria Creek near the Mariposa slates, 5.2 km southwest of Mariposa. It is composed of micropegmatite, quartz, oligoclase, biotite, ilmenite, and epidote. Orthoclase is probably present although not determined in the thin section. Some of the epidote is wedged in between the other constituents all of which are fresh. This epidote is probably primary.

No. 413 is from the interior of the area above described, 6.5 km west of Mariposa. This was estimated to be a fair average sample of the rock. It is composed largely of albite and micro-

pegmatite, with less quartz, titanite, apatite, epidote, pyroxene, and uralite. A rough calculation shows that this rock is composed of about 64 per cent. of albite, 25 per cent. quartz, the remaining 11 per cent. including pyroxene, titanite, apatite, epidote and uralite. It is thus a true soda-granite.

South of the locality at which 399 was collected, on Agua Fria Creek, the soda-aplite is in sharp contact with granodiorite, but there was no satisfactory evidence found of the relative age of the two rocks. At the head of Owen's Creek, to the west of Cathay Valley, there is better evidence of the age of the soda-granite. The clay slates, which are pretty certainly of Juratrias age, are here clearly metamorphosed by the granitic rock.

In Butte and Plumas counties white dikes are abundant in metamorphic magnesian rocks, which are altered peridotites and pyroxenites. These dikes are mostly composed of quartz and albite, but in some muscovite is present. Analysis 725 is of a specimen collected from a dike in serpentine on Grizzly Hill in Plumas county. It is composed chiefly of spherulites of quartz and albite, micropegmatite, and abundant muscovite, the latter mineral chiefly in little rosettes. It has elsewhere[1] been suggested that these dikes of soda-granite and aplite are in some way genetically related to the peridotites and pyroxenites or other basic rocks with which they are usually associated.

The aplite dikes in the gneisses and associated granites.— In the bed of the North Mokelumne and other points there are irregular white dikes in the gneisses and associated granitic rocks. Some of these dikes are of evenly granular texture throughout, and may be called aplites; others are banded. A chemical analysis has been made of only one of these dikes, and this analysis taken in connection with the microscopical examination indicates that the rock is rich in soda, and hence the aplites in the gneisses are placed with the soda-aplites. It is by no means certain, however, that they are all alike in composition. Some of these dikes contain garnets. The aplites in the gneisses and

[1] Bidwell Bar folio of the Atlas of the U. S. Geol. Surv.

older granite are supposed to be older than the potash-aplites of the granodiorite series.

PARTIAL ANALYSIS OF SODA-APLITE (NO. 1830). ANALYST, STOKES

SiO_2	76.17
CaO	1.64
K_2O	2.48
Na_2O	4.54

No. 1730 is a dike in gneiss from the north bank of the Mokelumne[1] a little below the mouth of Blue Creek in the Big Trees quadrangle. This rock is made up chiefly of quartz and feldspar. In addition there is a little biotite present. For the purpose, however, of a rough calculation this biotite can be ignored and all the lime ascribed to anorthite, all the soda to albite, and all the potash to orthoclase or microcline. Nearly all the alumina of the rock is contained in the feldspar molecules. The amount of alumina may therefore be calculated, and equals .1289 molecules, or by weight 13.15 per cent. The free silica can be estimated by deducting from the total silica the amount in the feldspar.

Total silica	1.2695
Silica in feldspar	.6562
Free silica	.6133

The molecular composition of soda-aplite No. 1730 is then approximately as follows.

	Molecules	Percentage
Potash-feldspar	.2112	13.83
Soda-feldspar	.5856	38.34
Lime-feldspar	.1172	7.67
Quartz	.6133	40.16
	1.5273	100.

The albite and anorthite molecules together form plagioclase, the ratio being $Ab_5\ An_1$; hence the plagioclase is acid oligoclase. The potash-feldspar is chiefly or entirely microcline. The relative abundance of the constituents of soda-aplite No.

[1] See Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 700–705, for other notes about these gneisses.

1730 may be stated as follows: oligoclase> quartz> microcline> biotite.

Quartz-diorite-aplite.—In the bed of Bear River, Big Trees quadrangle, there are small white dikes from two to ten centimeters or more in width, occupying straight fissures in gneiss and quartz-diorite. The dikes have an aplitic texture and are much more acid than the quartz-diorite. It may be assumed that they bear a genetic relation to the diorite, similar to that existing between the potash-aplites hereafter described and the granodiorite and quartz-monzonite. In the table of analyses with the soda-granites there is given the chemical composition of one of these dikes (No. 1490) as well as that of the quartz-diorite (No. 1495) in which they occur. No. 1490[1] is practically an aplite, the feldspar, however, being probably chiefly andesine. The enclosing quartz-diorite is quite basic and we thus have a suggestion that the composition of aplitic dikes is determined by the composition of the granitic rock in which they occur. Rosenbusch[2] refers to tonalite-aplite and diorite-aplite and the dikes above described might be designated tonalite or quartz-diorite-aplite, following Rosenbusch. It should be noted, however, that by some authors the term aplite is restricted to granites composed chiefly of quartz and alkali-feldspar. If, however, dikes occur in various magmas which, while varying in composition, show a direct genetic relation to these magmas, some group term for such dikes is desirable.

The potash-aplites and pegmatites of the granodiorite series.—At a great number of points in the Sierra Nevada, there are dikes of a white rock from a few inches to a few feet in width. In the granodiorite and quartz-diorite these dikes are usually medium-grained with only occasional dark constituents. They grade over into pegmatite. The pegmatitic facies will, however, be treated in a later paragraph. This aplitic granite is composed of quartz> potash-feldspar> soda—lime-feldspar (oligoclase)> biotite> magnetite> apatite.

[1] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 704.

[2] Mikroskopische Physiographie der massigen Gesteine, 1896, p. 464.

The chemical analysis given below shows more titanium oxide than is required for the biotite. Inasmuch as all the iron oxide is magnetic and therefore probably magnetite, it is likely that there is no ilmenite present. The remaining titanium oxide is therefore supposed to be present in titanite, which is the most common titanium mineral in the Sierra Nevada granites. This mineral was not, however, found in the thin sections. The relative proportions of these different minerals are taken from the calculation, as given below.

It is well known that as a general rule, the less siliceous elements crystallize out first and the more siliceous last in rock magmas. In most quartz-diorite and granitic magmas the alkali-feldspar and quartz are usually the last elements to crystallize, and they are, also, the most acid of the components of the rock. A possible explanation of the occurrence of aplite dikes in quartz-diorite and granitic magmas would appear to result from this law of crystallization. We have but to suppose that after the crystallization of the less siliceous constituents there is a residual mass of orthoclase and quartz in solution which is afterwards forced into fractures which form in the already consolidated granite, perhaps as the result of cooling. The laws of thermochemistry would appear to be applicable to such a scheme. Heat would be generated by the crystallization of the minerals of the granite and this heat would perhaps aid in establishing convection currents to transport the residual, more siliceous, constituents away from the already consolidated material. Moreover, as suggested by Dr. Hillebrand, the more siliceous material would be crowded away by the minerals which crystallize first, in the same way as the salt of sea water is crowded out by the crystallization of the water, so that the residual sea water, after a portion has crystallized or frozen, contains more salt, proportionately, than the sea water before crystallization began.

The following calculation of the relative molecular proportions of the various minerals found in the granodiorite-aplites is based on the average of two complete chemical analyses by Dr. Hillebrand, given in the table below. The calculation is

made in the same way as for the biotite-granite. The biotite in the aplites being similar to that of the biotite-granite, it is supposed to have the same chemical composition. The result of the computation is as follows.

COMPOSITION OF THE GRANODIORITE-APLITE

	Molecules	Percentage
Quartz	.6058	39.45
Potash-feldspar	.4520	29.43
Soda-feldspar	.3536	23.03
Lime-feldspar	.1008	6.56
Biotite	.0138	.90
Magnetite	.0061	.40
Titanite	.0027	.18
Apatite	.0008	.05
	1.5356	100.00
Total molecules	1.5523	
Not accounted for	.0167	

ANALYSES OF POTASH APLITES

	[159] Nevada city	No. 227 S. N.	No. 161 S. N.	Average of 227 and 161	Molecular proportions of the average
SiO_2	77.05[1]	75.97[2]	76.03[2]	76.00	1.2667
TiO_2	.....	.09	.07	.08	.0010
Al_2O_3	.....	13.07	13.39	13.23	.1297
Cr_2O_3	.....	none	.....	.....	.....
Fe_2O_3	.....	.61	.48	.54	.0034
FeO	.....	.39	.31	.35	.0049
MnO	.....	trace	trace	trace	.....
NiO	.....	none	.....	.....	.....
CaO	.73	1.49	1.28	1.38	
SrO	.....	.03	trace	.02	1.49 .0266
BaO	.....	.14	.04	.09	
MgO	.....	.14	.05	.09	.0022
K_2O	5.06	5.62	5.18	5.40	.0574
Na_2O	3.43	2.51	2.98	2.74	.0442
Li_2O	.....	trace	none	.....	.....
H_2O below 110° C.	.....	.14	.15	.14	.....
H_2O above 110° C.	.....	.24	.34	.29	.0161
P_2O_5	.....	trace	.03	.02	.00014
CO_2	.....	none	.....	.....	.....
Total		100.44	100.33	100.37	1.5523

Analyst: [1] Stokes. [2] Hillebrand.

159, N. C. is taken from Lindgren's paper in the Seventeenth Ann. Rep., U. S. Geol. Surv., Part 2, p. 45.

227, S. N. Dike in quartz-mica-diorite (No. 225, S. N.) about 3.2 km. east of Milton in the Downieville quadrangle The dike is about 60 cm. wide.

171, S. N. Dike in the quartz-mica-diorite about 11 km. east of the Sierra Buttes, Downieville quadrangle. The dike is quite wide and is intersected by joints, the most prominent set being nearly vertical.

Pegmatites.—The pegmatites which are associated with granodiorite and quartz-monzonite are very often banded, the border

FIG. 1.—Boulder of aplite-pegmatite on ridge south of Highland Creek in the Big Trees quadrangle.

of the dike being aplite and the middle layer pegmatite, thus forming a suggestion of the "comb" structure shown in some quartz veins. In certain cases the banding is repeated, there being several layers of aplite with pegmatite between. This is

shown in Fig. 1. In the more acid dikes or veins (?) the middle band is quartz with aplite borders.

It is not yet ascertained whether the aplites and pegmatites occurring in the different granites of the Sierra Nevada show characteristic differences that are constant. The oligoclase-aplite (No. 1730), previously described as coming from the North Mokelumne River, was presumed in the field to be typical of the aplites of the gneisses and biotite-granite; but it remains to be shown if there is not considerable diversity in these dikes. There are, for example, in the Yosemite quadrangle, in biotite-granite, sporadic bunches of white platy quartz interspersed with chunks of flesh-colored orthoclase or microcline. This forms practically a coarse pegmatite. The quartz in these bunches greatly exceeds in amount the potash-feldspar so far as my observation goes. One bunch of white quartz by the trail to the "Fissures" south of Yosemite Valley is 18 meters long and 14 wide, with chunks of potash-feldspar; but nine tenths of the mass is quartz. Some of the pegmatite in biotite-granite is distinctly banded,[1] the same as in granodiorite.

H. W. TURNER.

[1] Seventeenth Ann. Rep., U. S. Geol. Surv., Part I, p. 700, Plate XXXIV.

STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

V. MAMMALIA. — (*Continued.*)

HIPPOIDEA, *Equidae.* — The phylogeny of the horses has been made out by a study of the gradual changes which succeeded one another in the development of the modern form of the teeth and the foot structure. A nearly perfect series of these changes is known, and besides the direct line of the development of the horse, there have been demonstrated several side lines, all of which have become extinct. The earliest form that can be definitely stated as belonging to the line of the horses is *Hyracotherium*, from the Lower Eocene of the continent of Europe, England, and the United States. It is to be noticed that it does not occur in the lowest Eocene; thus it is not found in the Puerco of the United States, with the *Condylarthra*, but is found in the Wasatch, Green River, and the Bridger. There are four digits on the front foot and five on the hind foot, the three middle digits being functional on both feet; the fibula and the ulna of the fore part of the front and hind limbs are fully formed, and show nothing of the reduction that they subsequently undergo. The upper molars are different from the premolars, and are furnished with six tubercles, an outer pair and an inner pair, and between these another pair that is smaller.

Pachynolophus is from practically the same horizons as the *Hyracotherium* in America and on the continent. It represents a short step in advance; the ulna and the fibula are smaller and barely reach the end of the radius and the tibia. The two inner tubercles of the teeth are elongated laterally and almost join the two middle ones. This form includes, according to Osborn,

a large number of genera from both the old and the new worlds that have been described from separate teeth and fragmental bones.

Epihippus from the Uinta and Bridger and *Propaleotherium* from the Middle Eocene of the Paris Basin, are very close to the *Pachynolophus*, but the inner tubercles of the upper molars are more perfectly joined to the middle tubercles, so that there is a short ridge on both the anterior and the posterior portion of the inner side of the tooth.

Mesohippus from the Oligocene of the United States, White River, and *Paleotherium* from the Upper Eocene and the Oligocene of France, are the best representatives of the next step. In these forms there are only three digits on the front and hind feet, the fourth digit on the front foot being reduced to a mere splint bone with no trace of terminal phalanges. The ulna and the fibula are greatly reduced and scarcely reach to the distal ends of the radius and the tibia. The connections between the two inner sets of tubercles of the upper molars have developed into strong cross ridges which extend well out to the outer border of the tooth and nearly touch the anterior edges of the corresponding tubercles.

Anchitherium is now regarded as little off the main line of descent of the true horses, but as it represents very closely the succeeding stage that is properly indicated by a poorly known form, *Desmatippus*, from the Deep River beds of Oregon, it may properly be described here.

Anchitherium is one of the most common forms of the Upper and the Middle Miocene of the continent of Europe and the United States. The fourth digit of the front foot is reduced to a mere ossicle of bone at the upper end of the third digit. The distal ends of the ulna and the fibula have entirely disappeared, so that the bone ends free in the middle part. The teeth show the cross ridges of the upper molars extending out to the outer tubercles and joined with them. One of the most important changes of the series that developed the horse appears in this form; the enamel on the upper portion of the cross ridges dis-

appears and permits the cement below to appear at the surface. Now, as the cement is softer than the enamel, the wear of the tooth will serve to keep this inner part lower than the enamel walls, and there will always be sharp edges to serve for grinding up the grass and other herbage that forms the food of the animal.

Protohippus and *Merychippus* from the Pliocene of North America are the next forms in the series. The two lateral digits of the feet, two and four, are shortened and do not reach the ground, though they still retain all the phalanges. The ulna and the fibula are reduced to short splints, confined to the proximal ends of the radius and the tibia. The molars are very horse-like in the fact that all the tubercles have lost the enamel from the upper surfaces, and there are great "lakes" of cement, bordered by sharp enamel edges, for grinding the food.

Hipparion is a form somewhat off the line of the horses, but differs little from the *Protohippus*. It was very common in the Miocene time both in North America and in Europe. It extended up into the Pliocene in Africa and Asia.

Pliohippus and *Equus* are from the Pliocene deposits of most of the world, and from there upward the deposits of the Pleistocene and the recent times show their presence, except that *Pliohippus* is absent in the Recent. It is of interest to note that though the continent of North America was undoubtedly the original home of the horses and the theater of their greatest development, that at the end of the Pleistocene time they seem to have disappeared from the continent, and were only reintroduced by man when the Spaniards brought them over to aid in the conquest of Mexico.

The last two genera are distinguished by the reduction of the two lateral digits to two splint bones on the proximal end of the cannon bone and the nearly complete loss of the ulna and the fibula; the latter remains only as the olecranon process.

The phylogeny of the horse series has thus been arranged by Mr. Farr, a late writer on the subject.

Pliocene to Recent *Equus*

Hippidium

Loup Fork	*Protohippus*
	Hipparion
Deep River	*Desmatippus*
	Anchitherium
John Day	*Mesohippus*
White River	*Mesohippus*
Uinta	*Epihippus*
Bridger	*Pachynolophus*
Wasatch	*Hyracotherium*
	Paleotherium
Puerco	*Condylarthra*

The earliest of the horses must have presented a very different appearance from the horse as we know it. They were scarcely larger than a small dog and had rather the appearance of one than of a horse. The Miocene members of the group were about the size of a small pony, with very delicate limbs. According to Osborn, they were, in all probability, marked very much like the zebra. The *Anchitherium*, *Hipparion*, and the earliest true horses were somewhat smaller than the recent horse, but could not have been very different in their external appearance.

Paleotheridae.—This is the more primitive of the two families. It is known only from the Upper Eocene deposits of Europe, but there are several closely related later forms both in Europe and America. *Anchitherium* and *Pachynolophus*, described among the *Equidae*, are by some authors regarded as more closely related to the *Paleotheridae*.

Paleotherium, from the Upper Eocene of the Paris Basin, is the typical genus. The dentition is complete, but the premolars have assumed the appearance of molars. There were three toes on each foot, all reaching to the ground. The surfaces of the teeth are covered with enamel and have not begun to show the "lakes" of cement that characterize the teeth of the true horses. The largest, from *P. magnum*, was about the size of a rhinoceros.

The TAPIROIDEA has the two families *Tapiridae* and *Lophiodontidae*. In common with the other Perissodactyls, they seem to

have their origin in the earliest Eocene from some animal closely related to the *Hyracotherium*. In general they were stout-bodied animals of medium size, with three digits on the posterior foot and four on the anterior; the upper teeth developed in the more recent forms a pair of transverse parallel ridges that are characteristic of the group.

Early in the history of the group it divided into the two families, which took different lines of development, the *Tapiridae* working out the condition of the modern Tapirs and the *Lophiodontidae*, which assumed somewhat the characters of the rhinoceroses and became extinct in the late Eocene or Middle Miocene.

Tapiridae. — The line of development of the modern Tapirs is expressed as follows by Wortman and Earle: *Systemodon* of the Wind River; *Isectolophus latidens*, Bridger; *I. annectens*, Uinta; *Protapirus*, White River, and possibly *Tapiravus*, of the Loup Fork. Speaking of this family, Smith Woodward says: "The family thus characterized dates back to the Lower Miocene (White River Formation) in the United States of America, and apparently to the same remote period in Europe. In the Tapirs of this early date the premolars are slightly simpler than those of the surviving genus *Tapirus;* while *Tapiravus*, ranging through the Miocene and Pliocene of North America, is still somewhat primitive in the same feature. The typical *Tapirus* itself, however, is represented in Europe by several fine specimens from the Lower Pliocene of Eppelsheim, Hesse-Darmstadt (*T. priscus*), and from the corresponding formations in Hungary and southeastern Austria; also by remains from the Pliocene of France and Italy, and by detached teeth from the Red Crag of Suffolk. It is also to be noted that other teeth, indistinguishable from those of *Tapirus*, occur in an Upper Tertiary (probably Pliocene) formation in China. It is thus evident that during Miocene and Pliocene times these animals ranged over most of the warm and temperate lands of the northern hemisphere. Hence is explained the remarkable distribution of the existing Tapirs, which are confined to two widely separated areas, namely,

(1) certain portions of the Indo-Malayan region, and (2) the tropical parts of America."

Lophiodontidae.—In defining this family Osborn and Wortman indicate its position by referring to it as "A family of Lophodont Perissodactyls intermediate in position between the *Tapiridae* and the *Hyracodontidae*. The genera referred to this family are *Lophiodon* from the Middle Eocene of Europe, *Heptodon* of the Wasatch, *Helaletes* of the Bridger and Uinta, and *Colodon* of the White River.

Lophiodon has been considered as a very widely spread form in the Middle Miocene of Europe, but it now seems to be the opinion that many species have been wrongly referred to it that should properly be placed with genera *Colodon* and *Helaletes*.

The CHALICOTHEROIDEA is sometimes regarded as a separate suborder, the *Ancyclopoda* not being related directly to the Perissodactyls. They were aberrant animals related on the one hand to the Perissodactyls and on the other to the Edentates. In the structure of the foot there is a striking resemblance to the structure in the great ground sloths, *Gravigrada*, of the late Tertiaries of America. It was five-toed and turned so that the weight of the animal rested upon the outer side of the foot, and the digits terminated in strong claws. The teeth, on the other hand, were strikingly like the teeth of the Perissodactyl series. The suborder, or super-family, had its greatest development in the Miocene and Pliocene times.

Homalodontotherium is from the early Tertiary deposits of Patagonia. The primitive character is indicated by the complete dentition of the animal and the absence of any diastema. The humerus was very short and stout, indicating possible fossorial habits.

Macrotherium is a smaller form from the Middle Miocene of France and Germany. The condition of the teeth indicates a somewhat more advanced type. The fore limbs were much longer than the hind. The best known species was about nine feet in length.

Chalicotherium is the best known form from the United States.

It is found most commonly in the Loup Fork. Many teeth resembling *Chalicotherium* have been named from all parts of the world, notably China, Hungary, and Germany, indicating a very wide range for the genus.

From the Tertiary deposits of South America, in Patagonia, and the Argentine Republic come the remains of many animals that seem to be without representatives in any other part of the world. In some respects they resemble the Perissodactyls and, indeed, one of the orders is regarded by Zittel as a possible family of that group. Their relationships are, however, still too imperfectly known to permit of much discussion. Three orders are known, the *Typhotheria*, *Toxodontia* and *Litopterna* (*Proterotheridae* Zittel). Smith Woodward says they "must be little modified descendants of very primitive eutherian mammals."

TYPOTHERIA.—The order is peculiar among the ungulates, in that it possesses a well-developed clavicle. The limbs are unmodified and the dentition is nearly complete.

Pachyrucus and *Typotherium* are the best known genera. The first was somewhat the smaller of the two. The teeth are somewhat rodent-like in appearance and the dentition is not complete. There was a considerable diastema between the enlarged incisors and the premolars, the canines were wanting.

TOXODONTIA.—The second order of the South American group resembled in many of its characters the first, but lacked the clavicle, and the limbs were modified toward the ungulate type, there being but three toes on the fore and hind feet The animals were much larger than the previous order, reaching nearly the size of the rhinoceros in the genus *Toxodon*. The bodies of the animals were short and stout, and the head was placed on a very short neck low on the body. The two typical genera *Toxodont* and *Nesodon* are both from the Tertiary of South America, but *Nesodon* is from the earliest strata.

LITOPTERNA.—This order was much farther developed than the preceding, and in general appearance could not have been far from that of the modern horse. The primitive condition is indicated by the complete dentition and the stage of develop-

ment of the limbs. There were forms with only a single digit remaining, and others with three, resembling the Perissodactyls in this character, but the same animals had the tarsus built on the Artiodactyl plan so that they can belong to neither group.

Thoatherium and *Proterotherium* are small animals from the Santa Cruz formation of Patagonia. They were monodactyl, the second and fourth digits being either completely lost or greatly reduced in size.

Macrauchenia was much larger than the other two, and resembled the modern camel in size and some of the skeletal characters. The limbs were functionally tridactyl. The genus comes from the Pleistocene deposits of Argentina.

AMBLYPODA.—This suborder reached its greatest development in the Eocene time and died out at the close of the same period. The members of the suborder were all rather stout animals that reached, near the time of their extinction, the size of an elephant, or nearly so. The brain was very small and almost devoid of convolutions; there were five toes on each of the feet, and the bones of the limbs were complete, *i. e.*, the tibia and the fibula, and the radius and ulna, were separate and perfect. The group is generally divided into two families according to the characters of the teeth, skull and limbs.

Coryphodontidae were animals limited to the lowest Eocene of America, England and France. The greatest number and the most perfect specimens have been obtained from the Wasatch formation of the western part of the United States.

Coryphodon, the typical genus, was a short and rather stout animal about six feet long; the skull was elongated in the facial region with a rather broad muzzle armed with strong incisor and canine teeth; the feet were very short and strong with blunt toes. The brain cavity was very small and limited to a small part of the skull. The surface of the skull was without any bony excrescences or with only very faint ones.

Dinocerotidae: found in the Middle Eocene, Bridger; animals larger than the preceding family, and in general stouter and stronger. The skull was longer and without the anterior

enlargement of the muzzle; the dentition was weaker in that the incisors were lost entirely or in part, and the molars and premolars were small and weak. The canines were greatly enlarged and extended from the jaws as tusks that were protected by a flange of the lower jaw. The top of the skull shows three pairs of bony protuberances that were possibly the bases of horns. The brain was little, if in advance, of that of the *Coryphotondidae*.

Dinoceros (*Unitatherium*).—Characters given in the description of the family.

ARTIODACTYLA.—The families that we shall consider are the *Anthracotheridae*, the *Suidae*, the *Oreodontidae*, the *Hippopotamidae*, the *Camelidae*, the *Anoplotheridae*, the *Tragulidae*, the *Protoceratidae*, the *Cervicorna*, and the *Cavicorna*.

Anthracotheridae.—This is an extinct family that is found chiefly in the deposits of Europe and the East Indies. The earliest member of the group occurs in the Eocene of Europe. During the Miocene time it spread over the whole continent of Europe and over North America. The whole group appears to have died out in the Miocene. The animals were large, about the size of the rhinoceros, and from that down to the size of a pig. The head was long and low, with little development in the cranial region and a consequently small development of the brain. The teeth are of the low multitubercular type that is characteristic of the pig family. The feet have four toes on each foot and the metapodials of the middle pair are not united.

Anthracotherium, Oligocene, of Europe, England, and India, and North America.

Ancodus, Oligocene, of Europe, and North America.

Merycopotamus, Pliocene, of India.

Suidae.—This is a very large group that contains the existing hog. There are many primitive characters in the group, such as the complete dentition, and the generalized multituberculate teeth. The limbs have either four or two toes and the metapodials of the middle pair are not united. The living members of the family are found in Asia, Africa, Europe, and America.

Fossil forms of the group are found in the Eocene of Europe and North America, but the greatest development of the family came from the Pliocene to Recent. The origin of the *Suidae* is not at all well known, but there seems to be little doubt that they are the specialized branch of some carnivorous stem.

Achænodon, from the Bridger Eocene, has very strong canines and the cheek teeth are similar in many respects to those of the primitive *Carnivora*.

Elotherium, from the Oligocene of Europe and the United States, White River, is one of the ancestral forms. The head is long, the posterior teeth are multitubercular, the premolars are conical, and the canines and incisors are long and well fitted for grasping. The limbs were peculiarly long, and altogether the animal seems to have been a rather vicious type of carnivorous hog that had the running powers of a deer.

Platygonus, from the Pliocene and the Pleistocene of the United States, was a very small form that seems to have been the direct ancestor of the peccary.

Sus, the true hog, appeared in Europe and Asia, in the Upper Miocene and has continued ever since. There is no native member of the genus in the Americas.

Hippopotamidae.—The Hippopotamus is not known earlier than the Pliocene, and occurs in deposits of that age in England and in India. The existing forms are confined in Africa.

Oreodontidae.—This is an extinct group that is confined to the Miocene and the lower Pliocene of the United States. It is primitive in all of its characters; the dentition is complete and the fore limb has five digits; the metapodials are not united. One peculiar thing is that the anterior lower premolar tooth passed forward and acted as the canine, while the canine assumed the aspect and the function of an incisor. The sense of hearing was very acute, the bulla of the ear reaches, in some of the later forms a very large size. The animals were all small, never reaching a size larger than that of a Newfoundland dog, and in most cases were much smaller. From the manner of the occurrence of their remains it seems that they lived near the banks

of the lakes or streams and gathered together in great herds. The time of their greatest development was the Oligocene, and in the beds of the White River deposits the remains are found in the greatest abundance.

Protoreodon.—Uinta.

Agriochoerus.—White River, a peculiar form that had the toes terminated in sharp claws like the Sloths.

Oreodon.—White River.

Leptauchenia and *Cyclopedius.*—Upper Miocene, Deep River.

Camelidae.—The camels seem to have developed first on the North American continent in the Middle Eocene, Uinta, and Bridger, and to have died out in the Pliocene. They are peculiar in the much elongated head and the deficient anterior dentition. In the older forms the metapodials are separate as in the families already described, but in the later ones the two are joined and only a thin layer of bone separates the two medullary cavities.

In South America during the Pliocene time there were developed a large number of forms that became extinct, with the exception of the existing Llama. The genus *Camelus* appeared in Asia in the Lower Pliocene without known forerunners, and in North Africa at the beginning of the Pliocene.

Leptotragulus.—Unita.

Poebrotherium.—White River.

Protolabis.—Loup Fork.

Procamelus.—Loup Fork.

Anoplotheridae.—Small extinct forms that were developed in the Eocene of Europe and died out in the lower Miocene. They seem never to have extended beyond the limits of the continent of Europe. They were among the first to develop the selenodont form of teeth that is the characteristic form of the deers and the most of the ruminants.

Anoplotherium.—Eocene.

Dichobune.—Eocene.

Xiphodon.—Eocene.

Cœnotherium.—Miocene.

Tragulidae.—Small forms that began in the Eocene of Europe and spread over nearly all parts of the world in the Miocene and the Pliocene. *Tragulus* of the East Indies and *Hyæmoschus* of the west African region are still living members of the group.

The group is highly specialized. The median metapodials alone are functional, the second and fifth are reduced to mere splints at the upper and lower ends of the middle pair. The carpals and tarsals are united in some forms and the metapodials are elongated and united in many of the forms to a cannon bone. The elongation of the limb, due to the length of the metapodials indicates the great running and leaping powers of the form. The upper incisor teeth are wanting and in the males the upper canine is elongate and appears outside of the mouth as a long tusk.

Lophiomeryx.— Europe, Upper Eocene.

Prodremotherium.— Europe, Upper Eocene. Remarkable for the slender skeleton and the length of the limbs.

Gelocus.— Europe, Oligocene.

Dremotherium and *Amphitragulus.*— Lower Miocene, Europe.

Dorcatherium.— Miocene, Europe and Asia.

Leptomeryx and *Hypertragulus.*— North America, Miocene.

Tragulus appeared in the Pliocene of Asia, and *Hyaemoschus* is unknown from fossil remains.

Protoceratidae.—A small family resembling in many respects the *Tragulidae* of the old world. The group is confined to the upper part of the White River formation of the United States. There is only one well-known genus, the *Protoceras*, an animal that resembled the modern antelope, probably, as much as any recent form. The male is peculiar in the fact that the skull bore two or three pairs of horn cores. The female was without horns.

Cervicorna.—This essentially modern group appears in the Miocene of Europe and North America and has a considerable number of the members still living. The males have, in nearly every case bony horns that are shed every year, differing in this respect from the succeeding group in which there is a permanent horn core, and the horn proper is not shed. The upper incisors

are deficient or entirely absent, and the upper canines are either absent, small, or enlarged as in the *Tragulidæ*. The carpals and the tarsals are anchylosed in some forms and the metapodials are united to form a cannon bone. The whole structure of the skeleton indicates the lightness and the speed of the deer tribe.

Blastomeryx.— North America, Miocene and Pliocene.

Paleomeryx.— Europe, Miocene.

Helladotherium.— Europe and Asia, Upper Miocene. This form with the *Samotherium* of Europe are interesting as being the ancestors of the giraffe, *Camelopardalis*, which is found in the same deposits and then disappears from the record to appear again in the Recent in Africa.

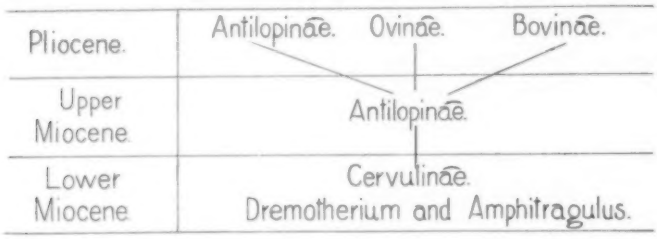
Sivatherium and *Bramatherium* are large forms, strikingly resembling the moose, which are known from the Miocene deposits of India and unknown since.

Most of the modern forms of the family seem to have appeared in the Pliocene and their remains are especially well preserved in the European deposits, but not until the Pleistocene time do the deposits indicate anything like the profusion of numbers and the widespread distribution of the group that obtains at present.

Cavicornia.— The group is in few particulars different from the *Cervicornia*. The horns are not deciduous or bony, they are present in both sexes. The teeth are similar in many respects, but the upper canine is always lacking as well as the upper incisors. The metapodials are always united to form a cannon bone and the lateral digits are the merest rudiments or are completely absent. In general the skeleton is very similar to that of the preceding group, but in many of the forms it is much more robust. One thing characteristic of the group is the width of the brow. Where the horns are set close together in the *Cervicornia*, in this group they are wide apart, a condition that reaches its greatest development in the *Bovidae*, the cows and buffaloes. It is of interest to note that the same loss of the enamel which took place on the upper surface of the teeth of the *Equidae* also took place in the *Artiodactyla*, and the later

forms have the enamel entirely removed from the tops of the tubercles and the spaces between the walls filled up with a softer and more rapidly wearing cement.

Three general divisions may be recognized, the antelopes, the sheep and the bovine tribe. The oldest of these, the antelopes, appeared in the Miocene of Europe and southern India. They seem to be derived directly from the *Cervulinae*, a subfamily of the *Cervicornia* represented by *Dremotherium* and *Amphitragulus*. During the Pliocene the three groups were differentiated.



PROBOSCIDEA.—The origin of this suborder is not at all well understood, the first members of the group are found in the Miocene time and in all the essential characters are as well developed as the most advanced of the living forms. In many of their characters the *Proboscidea* are very primitive; the structure of the feet and of the carpus and tarsus, the structure of the limbs and other parts of the body, are such as are found in the earliest ungulates. The development of the proboscis and the correlated shortening of the neck and the development of the peculiar dentition are the only characters that define the group. The most characteristic feature is the development of the incisor teeth as tusks which in some forms occur in both the upper and the lower jaws, in others in the lower jaws, and in the most modern forms in the upper jaws. In the earliest forms there were many teeth in the jaws, each one with strong transverse ridges completely covered with enamel; in the advance of the group the ridges on the teeth seemed to multiply until they became very numerous, and at the same time the enamel disappeared

from the top of the ridges, leaving the softer dentine exposed, which wore away more rapidly than the enamel and left strong, grinding ridges such as are found in the horse. With the advance in the structure of the teeth appeared the degeneration of the dentition as a whole, so that the modern elephant has never more than one cheek tooth at a time in the jaw; the teeth appear successionally, the anterior one first and so backwards during the life of the animal.

Dinotherium is the earliest known member of the group. It was characterized by the development of a pair of down-curving tusks in the lower jaw and a complete absence of incisors in the upper jaw. There was a more or less complete dentition, the jaw containing two premolars and three molars. The single complete skull known is about three feet long. The genus is known from the Miocene of Bohemia and from the Pliocene of Central Europe and India. It is unknown from America.

Mastodon differed from the preceding in the presence of fewer molar teeth and in the presence of tusks in both the upper and lower jaws or in the upper jaw alone. The molar teeth exhibit many variations in form, but in general the surface has a tendency to be distinctly tuberculated, the transverse ridges multiplying and dividing into outer and inner halves. In size the animal was nearly as great as the elephant. It was very common in the later Tertiary and forms have been discovered in formations as early as the Middle Miocene in Central Europe. In the Pliocene the genus seems to have reached a wonderful development and to have ranged over the greater part of the world; forms have been discovered in nearly every part of the world that man has visited. Near the close of the Pliocene it disappeared from Europe, but is found in the Pleistocene of America, sometimes associated with flint implements.

CARNIVORA.— The order *Carnivora* is one of the best known from the fossil forms. In the earliest Eocene they approach the *Condylarthra* to an extent that makes it difficult to tell the lines of the Ungulates and the Unguiculates (claw-bearing forms)

apart. The earliest of the *Carnivora* are placed in a suborder, the *Creodonta* opposed to the suborder *Carnivora vera* which includes the recent Carnivores and their immediate ancestors.

Creodonta.— These animals show their approach to the carnivorous type by the development of specialized cutting teeth, the appearance of claws on the feet and the assumption of the general form of the modern carnivores. Recent investigations show that this suborder is perhaps the most primitive of the modern mammals and is to be considered the ancestor of the ungulate type. Osborn, in a discussion of the questions of paleontology, said: "The most primitive type of Condylarth (*Euprotogonia*) and of Amblypod (*Pantolambda*) as recently studied by Osborn and Matthew, strongly reinforces the hypothesis first enunciated by Cope, *that the source of the Ungulata is to be found in the Creodonta.* Upon the other side of the great Mammalian tree, the numerous branches of Unguiculates or primitive clawed types also have converged towards a Creodont ancestry, as seen especially in the characters of the Ganodonta, or ancestral Edentates, and of the Rodentia, if Matthew's supposition proves to be correct also of the Tillodontia. Thus all these groups should be added to the Carnivora as Creodont derivatives. The Carnivora extend back into Creodont prototypes; but, as in the case of the Artiodactyla and the Perissodactyla, the actual points of contact or links between the two divisions are yet to be discovered." He extends the discussion to the position of the Creodonta with relation to the primates. He says: "The point of contact of the primates with the Creodonta is still entirely wanting, but their relations appear to be here rather than with the Insectivora.

"In spite, therefore, of the many remaining deficiencies or absence of links in our paleontological evidence, it has none the less come about *that the Creodont type takes the central position which was assigned by Huxley in 1880 to the Insectivora*, for the known Creodonta are more generalized and more central than any other of the known Insectivora, fossil or living, the known Insectivora showing a very considerable specialization, especially

in their dental succession, which places them apart as a distinct side phylum. This does not affect the derivation of the Creodonta themselves from stem forms of unspecialized Insectivora existing in the Jurassic period, the characters of which are seen in the *Insectivora Primitiva*, or placentals of the Stonesfield Slate and Purbeck periods."

The *Creodonta* are generally divided into eight families, which are here arranged as nearly as possible in the order of their evolution, which was directed toward the development of more perfect sectorial teeth and more and deeper convolutions on the surface of the brain.

Arctocyonidae: from the lowest Eocene of the United States, Puerco and Wasatch and the lowest Eocene of France.

Oxyclænidae: from the lowest Eocene of the United States.

Triisodontidae: from the lowest Eocene of the United States.

Mesonchyidae: from the Lower and Middle Eocene and possibly from the Miocene of the United States.

Proviverridae: from the Eocene of Europe and the United States.

Paleonictidae: from the Lower Eocene of the United States. This family is of some interest as containing the possible ancestor of the pinniped group of the true Carnivores.

Hyænodontidae: from the Eocene to the Miocene of Europe and America. This family has well-developed teeth of the sectorial type and approaches very close to the true carnivores.

Miacidae: from the Eocene of the United States. This family so closely approaches the modern carnivores that they have been placed among them by certain authors.

From the Lower Tertiary deposits of South America, Patagonia, come many forms that are undoubtedly Creodonts but of doubtful position in the suborder; by some authors they are placed among the *Hyænodontidae*, and by others they are placed in a separate group, the *Sparrassodonta*. The best known forms are *Prothylacinus* and *Borhyæna;* they are very similar in some respects to the carnivorous Marsupial, *Thylacinus*, of Tasmania.

The *Carnivora vera* are distinguished by the larger size of the brain with its deeper convolutions and the development of a single tooth in each jaw, the fourth premolar in the upper jaw and the opposing first molar in the lower jaw, as sectorial teeth. The suborder is generally divided into two groups : the *Fissipeda* or land living forms and the *Pinnipeda*, seals, walruses, etc.

Fissipeda. — Seven families are recognized, the *Canidae*, *Ursidae*, *Procyonidae*, *Mustelidae*, *Viverridae*, *Hyænidae* and *Felidae*.

Canidae. — The dogs appeared in the Upper Eocene of Europe and the Lower Miocene of the United States. They are descendants, probably, of the Proviverrine branch of the *Creodonta*. The development of the dogs has been toward the improvement of the feet as organs of locomotion ; the early forms had five toes on both the fore and the hind feet, but in the modern forms the first digit is wanting on the front foot and often on the hind foot as well. The teeth have developed from low crushing forms to the more typical carnivorous condition with the specjalized carnassials. Typical forms are :

Cynodictis and *Cephalogale*, Upper Eocene, Europe.

Amphicynodon, Oligocene, Europe.

Amphicyon and *Galecynus*, Miocene, Europe.

Daphænos and *Oligobunis*, North American Miocene.

The recent forms appeared in the Pliocene of Europe, Asia and North America, and in the Pleistocene of Africa and South America.

Ursidae. — The bears are distinguished by the plantigrade feet and the low multitubercular teeth without the specialized carnassials. They appeared in the Middle Miocene of Europe in the genus *Hyænarctos* and not before the Pleistocene in the other countries when the existing genera were developed.

Procyonidae. — The coons occupy a small place somewhere between the dogs and the bears. They were developed some time in the Pliocene and are today confined to the American and the South Asian regions. They are known from the Loup Fork beds of the United States.

Mustelidae. — The weasels and otters are among the most

specialized of the *Carnivora*. The first live almost entirely upon blood drawn from the veins of their victims and the second are aquatic in habit and great eaters of fish. They began their development in the upper Eocene and in that time and the Miocene a large number of forms were developed in Europe. After the Miocene they spread out and the deposits of all parts of the world, with the exception of Australia, are rich in their remains.

Viverridae.—A small group of cat-like animals confined to Africa, Asia and Southern Europe. They originated in the Eocene of Europe and only as late as the Pliocene appeared in others countries.

Hyænidae.—The hyænas are somewhere between the cats and the bears, the teeth are partly sectorial and partly crushing in form. They appeared in the Upper Eocene of Europe and Asia and are now known from those deposits with the addition of North Africa. *Hyænictis* is one of the first forms. It is from the Miocene of Europe and Asia.

Felidae.—The cats reach, perhaps, the highest point of the development of the *Carnivora*. The teeth are highly specialized; the molars seem to show a tendency to grow less in number and to assume more and more the form of the feline carnassials which are the highest type of that tooth form developed. The fore feet are modified to serve as organs of prehension as well as locomotion. The canine tooth reaches enormous proportions in some forms, and there is a process on the lower jaw to protect them as in the *Dinocerata*. They originated in the Upper Eocene and rapidly spread all over the world. The Oligocene, White River, of the United States is especially rich in the remains of these forms.

Eusmilus.—Upper Eocene of Europe.

Hoplophoneus, *Dinictis*, *Nimravus* and *Pogonodon*.—White River, United States.

Machairodus.—Pliocene, Europe, Asia, and the Americas. This form is remarkable for the great length of the upper canine. It was so long that it is possible that the animal could

not open its mouth wide enough to bring the teeth into play. It has been suggested that the teeth were used to aid it in climbing trees.

The existing genera of the cats were developed in the Pliocene and Pleistocene.

Pinnipeda.—The water living carnivores seem to have sprung, as has been suggested, from the Creodont *Patriofelis.* The existing families can be traced back as far as the Pliocene but beyond that there is nothing to connect them with the early forms. Fragmentary skeletons of seals and walruses have been found in the Pliocene of Europe and America.

INSECTIVORA.—The Insectivores are among the least changed of all the Mammals from their prototypes of the earliest Tertiary. The brain, carpus and dentition all present characters that are found in the Creodonts. Many of the existing families are found in the Eocene.

CHIROPTERA.—The bats are known from deposits as early as the Eocene in Europe and America, but nothing is known of their ancestry; the fossil genera, including those extinct, are very similar to the living forms.

RODENTIA.—The order is characterized by the absence of the canine teeth, the development of two incisors in the upper and the lower jaws as gnawing teeth which grow from persistent pulps and the arrangement of the articular condyle so that the lower jaw can slide backward and forward in the act of grinding up the food. There are many primitive characters in the group which is a remarkably persistent one, well-defined rodents being known from the early Eocene. Three suborders are known: the *Tillodontia, Duplicidentata* and the *Simplicidentata.*

Tillodontia.—These are forms that are known from the Eocene deposits of Europe and America. In these the canines are still preserved as rudiments, and there are sometimes more than the single pair of incisors in the lower jaw.

Esthyonx from the Wasatch and Bridger series of the United States is the earliest form known. A fragmentary skull from

the London Clay seems to indicate the presence of a related form in Europe.

Tillotherium from the Bridger of the United States is the largest form known; the skull measured about a foot in length. The developed incisor teeth are of large size, and the second pairs of incisors and the canines are even smaller than in the preceding genus.

Duplicidentata.—This group contains the hares and rabbits. They seem to have been developed about the Middle Miocene, *Paleolagus*, White River. During the Pliocene they spread over all of Europe and North and South America.

Simplicidentata.—This group is far larger than the preceding; it contains the rats, mice, squirrels, and all the remaining forms of the rodents. None of the forms appear before the Miocene, and during that time and the Pliocene differentiated and spread all over the world.

PRIMATES.—The order is divided into two suborders, the *Lemuroidea*, containing the lemurs, and the *Anthropoidea*, containing the apes and man.

Among the primitive lemurs are many forms which are so clearly intermediate between the two suborders that they must be regarded as the direct ancestors of the *Anthropoidea*. The living lemurs are confined to the island of Madagascar and to parts of Africa and southern Asia. In the Miocene and Eocene times they seem to have spread over the greater part of Europe and North America; they became extinct in the latter countries about the end of the Miocene time. Among the most important forms of the lemurs are *Anaptomorphus*, *Adapis* and *Megaladapis*.

Anaptomorphus is from the Wasatch Eocene of Wyoming; related forms are known from the lower Eocene of France and England. The animal exhibits the very large cerebral hemispheres that are characteristic of all the Primates and thus indicates the starting point of the specialization in the nervous system that has culminated in man.

Adapis is from the Lower Eocene of Europe; a closely related form is *Tomitherium* from the Eocene of New Mexico.

Megaladapis is a very large form from the post-Pleistocene of Madagascar. The skull was about two feet long. The animal seems to have lived in the island as late as the seventeenth century.

Anthropoidea.—The true apes do not appear until the middle of the Miocene; in Europe they seem to have extended over a large part of the continent as late as the Pliocene time, and one genus still exists upon the rock of Gibraltar. The genera of the apes multiply so rapidly that it is not possible to trace the development of the forms in any limited paper. It will perhaps suffice to note their occurrence in the Middle Miocene of France, the Pliocene of Germany, the Pliocene and Pleistocene of India and the early Tertiary of Patagonia.

In regard to the derivation of the human family, *Hominidae*, from the Primates Cope says (*Primary Factors of Organic Evolution*, chap. 11, p. 157. The phylogeny of man): "To return to the more immediate ancestry of man I have expressed and now maintain as a working hypothesis that all the Anthropomorpha were descended from the Eocene lemuroids. In my system the Anthropomorpha includes the two families Hominidæ and Simiidæ. The sole difference between these families is seen in the structure of the posterior foot, the Simiidæ having the hallux (great toe) opposable, while in the Hominidæ the hallux is not opposable. . . . . " "It is then highly probable that Homo is descended from some form of the Anthropomorpha now extinct, and probably unknown at present, although we do not yet know all the characters of some extinct supposed Simiidæ, of which fragments only remain to us."

Smith Woodward says of the earliest men: "Most of the evidence for the existence of the human race in the pre-historic past consists in traces of intelligent handiwork revealed by stone and other implements. A few discoveries in the old world, however, are worthy of consideration.

"The oldest known traces of a man-like skeleton seem to be an imperfect roof of a skull, two molar teeth, and a diseased femur, from a bed of volcanic ash containing the remains of

Pliocene mammals, near Trinil, in central Java. These are believed to belong to one animal which has received the name of *Pithecanthropus erectus*. The capacity of the brain-case is estimated to have been about two-thirds the average of that of man: the forehead is very low; and the supraorbital ridges are prominent. The inclination of the nuchal surface of the occiput is considerably greater than in the Simiidæ. The femur measures 0.455 m in length, and denotes an upright gait.

"The oldest human skeletons of which the geological age is determined with certainty, are two from the cavern of Spy, near Namur, in Belgium. These were found in association with remains of the mammoth and other Pleistocene mammals beneath a layer of stalagmite, which had never been disturbed, and which was also covered with earth containing bones of the same extinct quadrupeds. The skeletons, therefore, could not be the result of a comparatively recent burial, but were proved to have been contemporaneous with the associated animals and Palæolithic flint implements. They are essentially human in every respect, but seem to represent a race inferior in skeletal characters to any now existing. They are small, but powerfully built. The forehead is low; the supraorbital ridges are very prominent; and the chin is remarkably retreating. The radius and ulna are unusually divergent in the middle. The femur is somewhat bent, and the tibia is comparatively short, so that the leg cannot have been quite upright in walking. This type is now generally known as the *Neanderthal race*, the roof of a similar skull having been found associated with other fragmentary remains so long ago as 1857 in a cavern in the Neanderthal between Düsseldorf and Elberfeld, Germany."

In closing the discussion of the mammals, it is well to draw attention to the idea so forcibly set forth in Lydekker's book, *Geographical History of the Mammalia*, that all the mammals had a northern origin, and have attained their present position by gradual migration toward the south. Though the theory is still far from being proven, it should be of great interest to the student of geology because of the possibilities it presents for an

interpretation of climatic and land-mass conditions in the Tertiary time. Throughout the book evidence is constantly adduced to show the strength of the author's position. I shall quote merely enough of the introduction to give an idea of the theory.

Upon page 7 the author says: "There is a considerable probability that at least a very large proportion of the animals that have populated the globe in the later geological epochs originated high up in the northern hemisphere, if not, indeed, in the neighborhood of the pole itself (which is known to have enjoyed a genial climate during the Tertiary period), and that they gradually migrated southwards in a series of waves, probably under pressure of the development of new and higher types in high latitudes; and it is to such southerly migrations that the present marked differentiation of the fauna of different parts of the earth's surface is chiefly due. Whether such a northerly origin held good for the terrestrial life of the Secondary epoch, there are no means of determining; but it would appear that the higher animals (which were chiefly reptiles) of that epoch were very similar throughout the world, and that the differentiation of faunas had scarcely, if at all, commenced." .... "With mammals the case is very different. The earliest known forms, which date from the Triassic and Jurassic rocks, are chiefly marsupials and forms apparently allied to the monotremes, and it is probable that most of the descendants of these, as is more fully indicated in the sequel, migrated southwards during the early part of the Tertiary epoch, to find in Australasia a refuge from the competition of higher forms. Of the higher placental mammals, none of the modern types make their appearance before the Oligocene and Miocene periods, while many do not antedate the Pliocene. Their southern migrations accordingly took place later on in the Tertiary period, one of the earliest movements being the wandering of lemuroids, insectivores, and civet-like carnivores into South Africa and Madagascar. On the other hand, many other higher types, such as the hippopotami, giraffes, and antelopes, which were abundant in Europe and southern

Asia during the Pliocene, only left their more northern homes to find a permanent abiding place in Africa at a very late epoch in the earth's history."

E. C. CASE.

References.— Other than the books already referred to, the student will find the most helpful literature in the files and current numbers of *The American Journal of Science*, *The American Naturalist*, which contains a number of separate articles upon the different groups, by the late Professor Cope, the *Proceedings of the Philadelphia Academy of Science*, the *Proceedings of the American Philosophical Society*, *The American Geologist*, and *The Kansas University Quarterly*.

EDITORIAL

A PRELIMINARY circular of the French Committee of Organization for the Eighth Session of the International Geological Congress announces the date of the meeting to be held in Paris in 1900. The meetings will be opened on the 16th of August and will be closed on the 28th. They will be held in a building connected with the Exposition, and the hours will be so arranged as to give the members opportunity to visit the Exposition.

Field excursions are to be made a prominent feature of the session and will take place before, during, and after the meetings. These excursions are to be of two kinds, *general* and *special*. The first will be open to as large a number of members as possible, who may be taken to localities where hotel accommodations are adequate. The special excursions are intended for specialists, and since they may necessitate the visiting of regions poorly provided with hotels, the number of members who may participate in each excursion is limited to twenty. To compensate for the small number of geologists admitted to any one of these excursions, the number of excursions is increased to nineteen. This arrangement promises to be a satisfactory solution of the difficult problems connected with the geological excursions, which form so valuable a factor in the organization of the congress.

Of the general excursions three are announced:

1. Tertiary Basins of Paris, conducted by MM. Munier-Chalmas, Dollfus, L. Janet, and Stanislas Meunier.

2. Boulonnais and Normandie, conducted by MM. Gosselet, Munier-Chalmas, Bigot, Cayeux, Pellat, Rigaux — 10 days.

3. Central plateau of France, conducted by MM. Michel-Lévy, Boule, Fabre — 10 days.

The nineteen special excursions include:

I. Ardennes, conducted by M. Gosselet — 8 days.

II. Picardie, conducted by MM. Gosselet, Cayeux, Ladrière — 6 days.

III. Bretagne, conducted by M. Barrois — 10 days.

IV. Mayenne, conducted by M. Oehlert — 8 days.

V. Turonian Types of Touraine and Cenomanian Types of Mans, conducted by M. de Grossouvre — 6 days.

VI. Faluns of Touraine, conducted by M. Dollfus — 4 days.

VII. Morvan, conducted by MM. Vélain, Peron, Bréon — 10 days.

VIII. Coal Basins of Commentry and of Decazeville, conducted by M. Fayol — 7 days.

IX. Massif of Mont-Dore, Chain of Puys, and Limagne, conducted by M. Michel-Lévy — 10 days.

X. Charentes, conducted by M. Glangeaud — 8 days.

XI. Basin of Bordeaux, conducted by M. Fallot — 6 days.

XII. Tertiary Basins of the Rhône, Secondary and Tertiary Terranes of the Basses-Alps, conducted by MM. Depéret and Haug — 12 days.

XIII. Alps of Dauphiné and Mont Blanc, conducted by MM. Marcel Bertrand and Kilian — 10 days.

XIV. Massif of Pelvoux (High Alps), conducted by M. Termier — 10 to 12 days.

XV. Mont Ventoux and mountain of Lure, conducted by MM. Kilian, Leenhardt, Lory, Paquier — 10 days.

XVI. Basse-Provence, conducted by MM. Marcel Bertrand, Vasseur, and Zürcher — 10 days.

XVII. Massif of Montagne-Noire, conducted by M. Bergeron — 8 days.

XVIII. Pyrénées (crystalline rocks), conducted by M. Lacroix — 10 days.

XIX. Pyrénées (sedimentary rocks), conducted by M. Carez — 10 days.

Further notice of the excursions and a guidebook relating to them will be issued early in 1900. J. P I.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE[1]

Boss[2] describes the dikes associated with the ore deposits of the Gogebic iron range. They are dioritic and more or less altered; they are approximately at right angles with the dip of the formation they cut, and the greater number of them have an average easterly dip of 15° to 18°—sometimes they are folded in such a manner as to form long synclinal basins with eastward pitch. In a majority of cases mining exploitation has shown a succession of dikes, one below the other, and ferruginous quartzite of varying thickness immediately underlying each dike and forming the cap of the succeeding deposit of ore.

Comment.—The dikes have been shown by Irving and Van Hise[3] to be diabase, rather than diorite. With this exception, the above observations are in accord with and confirm those of Irving and Van Hise in this area, and except in a few details nothing new is presented. For a comprehensive discussion of the position of the dikes and their relations to the ore bodies the reader is referred to Monograph XIX of the United States Geological Survey.

Wadsworth[4] describes the origin and mode of occurrence of the Lake Superior copper deposits, and the age of the copper-bearing series. A reëxamination of the Douglass Houghton and Hungarian River areas shows that the Eastern Sandstone passes under the lavas with increasing dip, and that the junction is not a fault junction, but that of a lava flow upon an underlying soft sand and mud. It is held that the Eastern Sandstone is of Potsdam age, and underlies the copper-bearing series, the first lava of that series having flowed out upon the

[1] Continued from p. 854, Vol. VI, JOUR. GEOL.

[2] Some dike features of the Gogebic iron range, by C. M. Boss, Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 556–563.

[3] The Penokee-Gogebic iron-bearing series of Michigan and Wisconsin, by R. D. IRVING and C. R. VAN HISE: Mon. U. S. Geol. Surv., No. XIX, 1892.

[4] The origin and mode of occurrence of the Lake Superior copper deposits, by M. E. WADSWORTH: Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 669–696.

sandstone. The basaltic rocks forming the Bohemian Mountains present phenomena which indicate their eruption subsequent to the formation of the main deposits of the region, although the question is as yet open. Subsequent to the deposition of the Keweenawan a fissure was formed near the contact of the Eastern Sandstone and the lavas, along which normal faulting occurred, the copper-bearing series forming the overhanging side of the fault. As to the nature of the displacement, however, more evidence is needed. The copper occurs in fissure veins, in melaphyres, and in conglomerates.

Comments.—That the Keweenawan was deposited on the Eastern Sandstone was held by Wadsworth before the publication of Irving's[1] report on the copper-bearing series in 1883. In his report Irving presented evidence to show that this could not be the case, but that the sandstone is post Keweenawan; and later, in 1885, Irving and Chamberlin[2] in a more comprehensive discussion of the relations of the Keweenawan to the Eastern Sandstone, proved still more clearly the post-Keweenawan age of the Eastern Sandstone. Subsequently, in 1893, Wadsworth took the view that the Keweenawan formed the lower part of the Potsdam, and explained the phenomena on the theory that the Eastern Sandstone, instead of being one sandstone, may contain two or three sandstones of different ages. In the article above reviewed Wadsworth has gone back to his earlier view. However, he has not yet met the arguments so clearly stated by Irving and later and more comprehensively, by Irving and Chamberlin.

Berkey[3] describes and maps the geology of the St. Croix dalles of Wisconsin and Minnesota. Keweenawan eruptives are exposed at numerous localities, and particularly along the river, where, by their erosion, they have formed the dalles of the St. Croix River. The dip is about 15° to the south, which would give a thickness to the rocks in sight of 4000 feet. At several localities the Basal Sandstone unconformably overlies the Keweenawan eruptives with visible contacts, the

[1] The copper-bearing rocks of Lake Superior, by R. D. IRVING: Mon. U. S. Geol. Surv., No. V, 1883.

[2] Observations on the junction between the Eastern Sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. IRVING and T. C. CHAMBERLIN: Bull. U S. Geol. Surv., No. XXIII, 1885.

[3] Geology of the St. Croix Dalles, by C. P. BERKEY: Am. Geol., Vol. XX, 1897, pp. 348–383, and Vol. XXI, 1898, pp. 139–155, 270–294.

Basal Sandstone including the sandstone and shale series between the Keweenawan and the St. Lawrence shales.'

Winchell[1] discusses the significance of the fragmental eruptive débris at Taylor's Falls, Minn. This has heretofore been regarded as a conglomerate resting unconformably upon the Keweenawan. As a result of recent field work by Mr. C. P. Berkey, it is believed that this conglomerate may be separated into two conglomerates, an upper one at the base of the upper division of the Cambrian, and a lower one at the base of the lower division. The latter would come within the Keweenawan, as this term is used by Irving and other writers, and would separate this series into two parts.[2] The later conglomerate rests directly upon the earlier one, leading to the previous confusion of the true relations. Similar conglomerates found in the Keweenawan at several points between Duluth and Grand Portage have led to the conclusion that the Keweenawan may be divided into two great series, separated by conglomerate and quartzite which reach a thickness of several hundred feet. The lower series has been included in the Norian, and the upper series comprising the sedimentaries and the eruptives above them, has been called Keweenawan, the Keweenawan forming the lower division of the Cambrian.

Comments.— While the conglomerate within the Keweenawan at this locality has not before been noted, the occurrence of many conglomerates at other localities in the middle and upper part of the Keweenawan has been mapped and described by the Michigan and United States geologists, as a glance at Marvin's Eagle River section[3] and Irving's general report[4] on the Keweenawan will indicate. Instead of one conglomerate, there are a dozen conglomerates at different horizons. However, these conglomerates are composed almost without exception of local material, derived wholly from contemporaneous lava flows, and are held to mark very insignificant breaks in the series. As seen from Winchell's description, the Taylor's Falls conglomerate belongs to this class. The United States geologists, recognizing the

[1] The significance of the fragmental eruptive débris at Taylor's Falls, Minn., by N. H. WINCHELL: Am. Geol., Vol. XXII, 1898, pp. 72–78.

[2] In a recent paper, above summarized, MR. BERKEY (Am. Geol., Vol. XX, p. 381) takes the view that the lower conglomerate is a flow breccia of the igneous rocks.

[3] Geology of Michigan, 1873, Vol. I, Part II, Copper-bearing rocks, pp. 117–140.

[4] Copper-bearing rocks of Lake Superior, Mon. V, U. S. Geol. Surv., 1883.

local character of the conglomerates, have considered the series including them as a unit, and, regarding the hiatus at the top of the series as much more profound than that at the bottom, have included the series in the Algonkian, rather than in the Cambrian. Winchell and many of the Canadian geologists, on the other hand, have recognized but one conglomerate within the Keweenawan, and, giving this undue significance, have extended the Cambrian downward to this conglomerate, thereby including in the Cambrian the profound unconformity separating the Keweenawan series and the fossil-bearing Cambrian. If Winchell's reasoning be carried to its logical conclusion, wherever a conglomerate is found within the Keweenawan, the series must there be divided, and in place of one series, we shall have many series, a division which cannot be considered reasonable. It appears, therefore that Winchell's division of the Keweenawan into two series, on the basis of local conglomerates such as the one described from Taylor's Falls, is purely arbitrary, and furthermore, by referring his upper division to the Cambrian, the profound unconformity known to exist between the true Cambrian and the Keweenawan is practically ignored.

Winchell[1] discusses the Archean greenstones of Minnesota, which he considers the oldest known rocks, representing the original crust of the earth. The greenstones are divisible into two parts, one igneous and the other clastic, the latter succeeding the former with a confused, and apparently sometimes conformable superposition, somewhat as surface eruptive rocks might be superposed, in the presence of oceanic action, upon a massive of the same nature at the same place. The clastic portions of the greenstones vary to more siliceous rocks, constituting great thicknesses of graywackes, phyllites, and conglomerates, and as such have been converted by widespread metamorphism into mica-schists and gneisses.

As the Laurentian gneisses and granites cut the schists and sedimentary gneisses they are also younger than the bottom greenstones.

The metamorphic schists and gneisses seem to be representative of the sedimentary portion of the Lower Laurentian of Canada, while the igneous granite and gneisses are as plainly a general parallel of the igneous portion of that series. It follows, therefore, that the Canadian Laurentian is, as a whole, of later date than the greenstones, if the

[1] The oldest known rock, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci. Vol. LXVII, 1898, pp. 302, 303 (Abstract).

succession is the same as in the Northwest, and that the greenstones should be considered the bottom rock of the geological scale.

Winchell[1] attempts to explain the origin of the Archean igneous rocks. From field evidence and petrographic discriminations and associations, it is believed that the alkaline magma from which the igneous rocks were derived is the result of aqueo-igneous fusion of the fragmentals of the Archean itself; that when deeply buried, under heat and pressure, the Archean clastics were rendered plastic, penetrating openings in the adjacent and superjacent strata; and that when the plastic mass was not moved from its place it was simply recrystallized *in situ*.

The clastic rocks must have been derived from the basal greenstone, which is considered representative of the original crust of the earth. The presence in such clastics of sufficient potassa and silica to yield upon fusion the granitic magmas is explained on the hypothesis that they must have come from the waters depositing the fragmentals, and primarily from the atmosphere, in its condition normal to the Archean age, just following the congealing of the first crust.

While numerous instances of such transition from clastic to igneous rock have been noted in Minnesota, there has been a careful study of but one. That was the case of the granite and porphyry which intrude the clastics at Kekequabic Lake.

Winchell[2] presents some additional points on the geology of northeastern Minnesota.

The Laurentian includes, in Minnesota, an acid crystalline schist of sedimentary origin, and a massive igneous rock, although the igneous rock is younger than the crystalline schist portion, and should have a different designation. The conclusions reached are that: (1) the sedimentary Laurentian is a crystalline condition of sedimentary strata, which are conformably a portion of the sedimentary schists; (2) the igneous Laurentian is the result of a more intense metamorphism, carried even to fusion of some strata. These conclusions result particularly from the study of a section from Tower northward, through Vermilion

[1] The origin of the Archean igneous rocks, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XXII, 1898, pp. 299–310.

[2] Some new features in the geology of northeastern Minnesota, by N. H. WINCHELL: Am. Geol., Vol. XX, 1897, pp. 41–51.

Lake, and of an area on the west side of Outlet Bay, in the corners of sections 13, 14, 21, and 32, T. 63 N., R., 17 W., and along the shore for one half mile westward.

It is evident that the Stuntz conglomerate on the south shore of Vermilion Lake is a true water-deposited conglomerate, of the same formation as the slates and graywackes of the district, the conglomerate grading into the quartzite and graywacke, and this into argillaceous slate. Furthermore, as supposed by Van Hise, the conglomerate lies unconformably on the iron-bearing formation, and contains very numerous fragments of jaspilite. The position of this unconformity, whether at the base of the Taconic or lower is not ascertained.

The nature and position of the conglomerate in the valley of the Puckwunge, a small stream entering the Pigeon River north of Grand Portage, is discussed. This conglomerate is overlain by igneous rocks, resembling the traps of the Keweenawan. The subjacent formation cannot be certainly determined, but in the same locality, at a lower level, is a slate rock, called the Puckwunge slate, which was followed for some distance north and east, and which is probably an upper member of the Animikie, not before individualized. The conglomerate contains quartzite pebbles, which are referable to the quartzites of the Animikie, farther north. It may be inferred that this is the basal conglomerate of the Keweenawan, which has been identified up to Grand Portage island, and at intervals along the Lake Superior coast, from Baptism River to near Beaver Bay.

Winchell[1] discusses some resemblances between the Archean of Minnesota and of Finland. The succession in northeastern Minnesota, as made out largely from field work done in 1897, is as follows, in descending order.

1. *Granitic intrusion*, cutting and metamorphosing the earlier schists and fragmentals. This rock is seen about Snowbank Lake and Moose Lake, about the western confine of Disappointment Lake, and at Kekequabic lake.

2. *Upper Keewatin.*—This consists of conglomerates (at Stuntz Island and at Saganaga and Ogishkie Muncie lakes), sericitic schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids. The mica-schists, embracing many conspicuous bowlder-

[1] Some resemblances between the Archean of Minnesota and of Finland, by N. H. WINCHELL: Am Geol., Vol. XXI, 1898, pp. 222–229.

like forms on the weathered surfaces, are to be seen about Moose Lake, and southeast to Snowbank Lake, about Disappointment Lake, Kekequabic Lake, and eastward to Zeta Lake.

3. *Granitic intrusion*, chiefly represented by the granite of Saganaga Lake, where the Upper Keewatin lies unconformably upon it. It is also seen a little west of Ely and on the Kawishiwi River. At West Seagull Lake this granite cuts older greenstones and green schists.

4. *Lower Keewatin or Kawishiwin.*—This is mainly a greenstone formation, both massive and fragmental, and constitutes the oldest formation in the state. When stratified it consists of basic tuffs, agglomerates, and green stratified schists and greenwackes. It contains the banded jaspylites and iron ores at Vermilion Lake. Where cut by granite and porphyry (1), these rocks are converted to mica-schist and banded gneiss.

Unconformably above all these is the Animikie formation, of Taconic age, the base of the Paleozoic.

Nos. (1), (2) and (3), above, are paralleled in Finland by similar rocks in similar order, as described by Sederholm. Rocks corresponding to No. (4), the Lower Keewatin, seem to be wanting, or are seen only as inclusions in the next younger granite.

It is probable that the divisions above detailed for Minnesota and Finland are wholly embraced in the lower division of the Canadian Laurentian, *i. e.*, in the Ottawa gneiss, and that they have not yet been noted in Canada. The fundamental gneiss of Canada is, therefore, not the bottom of the geological series, but is largely a sedimentary series, derived from an older series, this older series being in part at least a greenstone, as indicated by the stratigraphic succession in Minnesota.

Comments.— In the above papers Winchell has modified his ideas from time to time with reference to the general succession of the pre-Cambrian rocks of northeastern Minnesota, and it may be well briefly to summarize what appear to be his latest conclusions. The succession from the base upward is as follows: (1) greenstone, both massive and fragmental, called the Lower Keewatin; (2) cutting this is a massive granite, typically developed at Saganaga Lake; (3) unconformably above the Lower Keewatin is a series of sedimentary rocks, consisting of conglomerates, sericite-schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids, called the Upper Keewatin; (4) granite cutting and metamorphosing all the preceding.

The correlation of the Minnesota series with the Ottawa gneiss and with the Finland series must be considered a pure conjecture. The Minnesota succession is not agreed upon; these widely separated regions have not been connected by structural work, and of course in the case of Finland never can be; and lastly, fossil evidence is lacking. Any correlation of the ancient crystalline rocks without the basis of connecting structural work or fossil evidence, must be considered as little more than a guess, having no foundation in inductive knowledge.

The massive igneous rocks of the Laurentian, mostly granites, which intrude the sedimentary rocks, are believed by Winchell to be due to the aqueo-igneous fusion of the lower portion of the sedimentary rocks, and the intrusion of the magma thus formed into the overlying sediments. The argument adduced in favor of this origin is based almost entirely upon an occurrence cited at Kekequabic Lake of a transition from igneous rocks to the clastic rocks there found. In 1891 and 1892 Grant[1] studied this area, and found no evidence of a transition from the semicrystalline and crystalline schists into granite. On the contrary, abundant evidence was found of the eruptive nature of the granitic rocks in the surrounding sedimentaries. The same area was closely studied by a party of the U. S. Geol. Survey during 1898, and the same conclusion was reached. The principal support of Winchell's theory is thus taken away, and it stands as an unproved hypothesis.

Grant[2] describes and maps the geology of Kekequabic Lake in northeastern Minnesota. By far the larger proportion of the rocks represented are clastics, which are divided for convenience into four groups. The first and most extensive group is the slate formation, consisting largely of argillites, with smaller amounts of fine and coarse graywackes and grits, the coarser phases becoming distinctly conglomeratic in places. The second group consists of coarse conglomeratic rocks, which are a part of the Ogishke conglomerate. The third group is made up of certain fissile green schists, which are believed to be water deposited, and probably originally formed from fine volcanic ash. The fourth

[1] Twentieth Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., 1893, pp. 69–82; and Twenty-first Ann. Rept., *ibid.*, pp. 50–54.

[2] The geology of Kekequabic Lake in northeastern Minnesota, with special reference to an augite soda granite, by U. S. Grant: A thesis accepted for the degree of Ph.D in The Johns Hopkins University, 1893. Published in Twenty-first Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., for 1892, pp. 5–58, 1893. With geol. map and plates.

group consists of volcanic fragmental material, in part deposited in water. All of these clastic rocks now stand in nearly vertical positions, with a strike a little north of east.

Sharply marked off from the clastic rocks are four types of igneous rocks, hornblende-porphyrite, granite, diabase, and gabbro. The granite is divisible into two types, ordinary granite, and granite-porphyry, in both of which the ferro-magnesian constituent is almost exclusively pyroxene and the predominating feldspar anorthoclase. The origin of the granite is truly eruptive; having broken through the surrounding clastics; the rock is not formed, as held by N. H. and A. Winchell, from the recrystallization in situ of the sedimentaries of the region.

The slate formation, the green schist, and the volcanic tuff belong to the Keewatin, the Minnesota equivalent of the Lower Huronian. The conglomerate contains pebbles, many of which are similar to some of the Keewatin rocks, and it seems to belong to a newer series, although as yet no unconformity between the conglomerate and other rocks has been discovered. Following Lawson, it is believed that the conglomerate is a part of the Keewatin, probably separated from the lower part of that series by an unconformity, and that it is much older than the Animikie. However, the question whether the clastics belong to one or two series is as yet open.

The porphyrite and the granite are of Keewatin age. The porphyrite is regarded as contemporaneous with the deposition of volcanic tuff and green schist, and the granite is believed to date from the folding of the Keewatin. The age of the diabase dikes is not known; they are perhaps contemporaneous with the great diabase intrusions in the Animikie. The gabbro is of early Keweenawan age.

Grant[1] sketches the geology of the eastern end of the Mesabi iron range in Minnesota, including T. 64 N., Rs. 3 and 4 W., and parts of Rs. 2 and 5 W., with some adjacent portions of Ontario. The rocks can be separated into three divisions. The chief one of these is the Animikie series, containing the iron-bearing rocks of the Mesabi range. Older than the Animikie is a series of granites, greenstones both massive and schistose, conglomerates, slates, and other clastic rocks, called the pre-Animikie. Younger than the Animikie are some diabase sills and the great gabbro mass of northeastern Minnesota.

[1] Sketch of the geology of the eastern end of the Mesabi iron range in Minnesota, by U. S. GRANT: Engineers' Year Book, Univ. of Minn., 1898, pp. 49–62. With sketch map.

Of the pre-Animikie rocks, the greenstones and clastic rocks have been called Keewatin. As the greenstones are usually associated with the Mesabi iron-bearing rocks, these alone of the Keewatin rocks are described. They lie to the north of the iron-bearing rocks in T. 65 N., R. 5 W., and extend eastward to the center of T. 65 N., R. 4 W., where they disappear under the Animikie strata. In general, the greenstones are at present diorites; originally some were certainly diabases, others were of the nature of andesites, and a large part were diorites, or possibly gabbros. At places, especially along the east side of Sec. 27, T. 65 N., R. 5 W., the greenstones contain angular and subangular fragments of rock almost like themselves, and some may be regarded as composed of fragmental volcanic rocks. Associated with the greenstones, especially in Secs. 22, 23, and 24, T. 65 N., R. 5 W., are small masses of more acid rocks, quartz porphyries and quartzless porphyries, which are probably younger than the greenstones.

The pre-Animikie granite has its typical development on the shores of Saganaga Lake. In a number of places it may be seen in intrusive relations with the greenstone. A quarter of a mile south of the N. E. corner of Sec. 23, T. 65 N., R. 5 W., many granite dikes cutting the greenstone are seen, and on the south shore of West Seagull Lake granite dikes of the same nature as the immediately adjacent main mass of Saganaga granite are seen cutting the greenstone. Both granite and greenstone are cut by another series of finer grained, more acid granite dikes.

The Animikie rocks rest unconformably upon the pre-Animikie rocks, and usually on the southern slope of the Giant's Range, which is composed essentially of granite. The strike is approximately E. N. E., and the dip in general about 10° E. of S. The thickness varies from nothing to 4000 feet. The Animikie is separable into four conformable divisions: (1) the lower or quartzite member, called the Pewabic quartzite; (2) the iron-bearing or taconyte member; (3) the black slate member; (4) the graywacke-slate member.

(1) The quartzite member is well developed in Itasca county, but disappears before reaching the eastern side of St. Louis county.

(2) The rocks of the iron-bearing member are similar to those in St. Louis county on the western end of the range, described by Spurr.[1] They differ, however, in two features. They are more completely

[1] Geol. and Nat. Hist. Surv. of Minn., Bull. X, 1894.

crystalline, and the iron is magnetite instead of hematite. The rocks consist chiefly of jaspers, amphibole (grünerite) schists, greenish siliceous slates, cherts, cherty carbonates, and magnetite slates. It is believed that these rocks were originally glauconitic green-sands; that the ore has been derived from the iron in the glauconite, and that the ore bodies result from concentration and replacement. In this part of the Mesabi range no ore bodies have yet been found which are at the same time both rich enough and large enough for profitable mining, although vast quantities of magnetite ore occur at or near the surface.

The dip of this formation varies from an average of 45° to 50° on the west to less than 15° on the east, and the thickness varies from 650 feet or less on the west to 900 feet on the east.

(3) The black slate is essentially a fine-grained, black, more or less siliceous, apparently carbonaceous slate.

(4) The graywacke-slate member is composed of black to gray slates and fine graywackes, with some flinty slates; the upper part shows coarser detrital material, and the highest beds seen are fine-grained quartzites and quartz-slates. This member is well exposed on the south shore of Loon Lake.

Associated with all of the strata of the Animikie are diabase sills, and bounding the Animikie rocks on the south is the great gabbro mass. These are igneous rocks of later date than the Animikie. Near the contact with the gabbro the Animikie rocks show marked metamorphism, and usually complete recrystallization. The gabbro varies from a nearly pure plagioclase rock to titaniferous magnetite.

The pre-Animikie rocks here described, according to the nomenclature used by the United States Geological Survey, belong to the Lower Huronian series of the Algonkian system, and probably also in part to the older Archean or Basement Complex; the Animikie is regarded as the equivalent of the Upper Huronian series of the Algonkian, and the gabbro as the lower part of the Keweenawan series of the Algonkian.

Winchell, Alexander,[1] gives a detailed petrographical description of the Koochiching granite occurring on the north boundary of Minnesota, about two miles west of Rainy Lake. The rock is a biotite-hornblende granite of eruptive origin, and is assigned to the Laurentian.

[1] The Koochiching Granite, by ALEXANDER WINCHELL: Am. Geol., Vol. XX, 1897, pp. 293–299.

Coleman makes notes on the petrology of Ontario, including the Port Coldwell, Missanabie, and Wahnapitae areas.[1]

Coleman makes a third report on the gold region of western Ontario.[2]

The districts visited and here reported upon are the Upper Seine district, the Shoal Lake district, the Manitou district, the country crossed between Manitou Lake and the Lake of the Woods, the Lake of the Woods district, the West Shoal Lake district, the neighborhood of Rat Portage, and the vicinity of Fort William on Lake Superior. As in previous reports, the general geology worked out by Lawson for the Lake of the Woods and Rainy Lake districts is accepted, and the general principles applied to other districts of the region visited.

In previous years it has been held that gold was to be looked for only in the Huronian. During the past three years, however, it has been found that some of the most promising gold deposits occur in the granite or gneiss. It has also been found that the best veins, or other ore deposits, occur at or near the contact of the Laurentian eruptive rocks and the Huronian.

In the Ontario region the gold deposits occur in the following ways. (1) True fissure veins, commonly found in the areas of massive eruptive granite. (2) Lenticular or bedded veins, confined to the schistose rocks. These are intercalated between the schists and run parallel with their strike, and are not so continuous as the fissure veins. (3) Contact deposits, between the Huronian and Laurentian. These are rare in this district. (4) Fahlbands of schists, impregnated with pyrites and other sulphides. (5) In quartz, associated with dikes of porphyry or felsite, near the contact of the Huronian and Laurentian rocks, penetrating the schists, and sometimes the granite itself. (6) In an eruptive mass, in but one locality. (7) Placer deposits.

Coleman[3] gives an interesting general account of the clastic Huronian rocks of Western Ontario, in the region extending from the Lake of the Woods in the west to Lac des Mille Lacs on the east, a

[1] Notes on the petrology of Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1898, pp. 145–150.

[2] Third report on the west Ontario gold region, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1897, pp. 71–124.

[3] Clastic Huronian rocks of Western Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 151–160. Published also in Bull. G. S. A. Vol. IX, 1898, pp. 223–238.

distance of 200 miles, with a width north of Rainy Lake of 120 miles. The Huronian, including the Keewatin and Couchiching rocks, is in general an immense series of water-worn sediments, in the upper part mixed with eruptives, perhaps largely later injections, but partly pyroclastic. The Keewatin is largely of eruptive origin, though it contains important sedimentary members; the Couchiching is entirely sedimentary.

The Keewatin, and in the southern part of the region the underlying Couchiching, form sharp synclines, curving as wide meshes around the areas of Laurentian, which vary from less than a mile to fifty miles in diameter.

Diabase and porphyry eruptives form an important part of the Keewatin. These are in large part surface flows, represented by ash rocks, agglomerates, etc., but many of them are probably laccolitic sills. The water-formed clastics of the Keewatin, include limestones, slates, quartzites, grits, graywackes, breccias, and pebble and bowlder conglomerates. The limestones are of limited extent, being found in any thickness only at Steep Rock Lake. The slate on analysis yields 7.44 per cent. of carbon, pointing perhaps to the presence of life. The conglomerates are in places schistose. Near Shoal Lake the most common pebbles are quartz-porphyry and porphyrite, felsite, and green schists indistinguishable from the adjoining Keewatin schists; black and red quartzite, white pulverulent sandstone, vein quartz, and anorthosite. No gneiss or granite pebbles have been found. Most of these pebbles are easily matched by Keewatin rocks, sometimes, however, many miles distant; a few are evidently Couchiching; and none are Laurentian.

The break represented by this conglomerate comes high up in the Keewatin, instead of at its base, just above the Couchiching, as held by Lawson. Striking evidence that the break is not at the base of the Keewatin is found at Shoal Lake, where a few bowlders of the coarse-grained anorthosite found in the schist-conglomerate are exactly like portions of a boss of anorthosite two miles away. As this anorthosite area contains masses and strips of characteristic Keewatin schist, swept off during its eruption, it is evident that an immense lapse of time separates the conglomerate and the underlying Keewatin. It is probable that the conglomerates represent an important interval of erosion, perhaps equivalent to the one shown by Van Hise and others between the Upper and Lower Huronian in the states to the south.

The Couchiching rocks are all formed of clay sand, more or less metamorphosed; in general they are biotite-schists or gneisses, the quartz showing a clastic origin. The Couchiching passes up by transition into the Keewatin, and there is no reason why the two together should not be classed as Huronian.

Following Lawson's estimate, the Keewatin and Couchiching series together sum up 50,000 feet in thickness.

The term Laurentian is employed, as Lawson and other Canadian geologists are accustomed to employ it—in a petrographical and structural sense—for crystalline gneisses and granites underlying the Huronian, although it is evident that these rocks have consolidated at a time later than the Huronian.

As described by Lawson, the Laurentian (Lower Archean) "occurs in large isolated central areas, more or less completely surrounded by the schists of the upper Archean, the encircling belts anastomosing and forming a continuous mesh work." It consists chiefly of a coarse reddish, often porphyritic rock, usually granite in the central part of the area, but showing a foliation, generally parallel to the periphery, where it comes in contact with the Huronian.

Throughout the region the Laurentian is in eruptive contact with the Huronian, and nowhere is a basal conglomerate of the Huronian found. Near the contact with the Huronian, strips and fragments of the Huronian are embedded in the gneiss; also dikes of granite, pegmatite or felsite generally run from the gneiss into the Huronian. The larger areas of gneiss and granite are evidently batholites. Some of the smaller granite bosses may be stumps of old volcanoes. The Huronian schists usually dip rather steeply away from the gneiss, at an angle seldom less than 45°. Finer-grained granites cut both the Keewatin and the Laurentian. However, it is not easy to say whether a given granite is Laurentian or a later granite.

It is believed that as a result of the piling up of a thickness of eight or ten miles of sediments and eruptive materials, represented by the Keewatin and Couchiching rocks, the slowly rising isogeotherms softened or fused the foundation, which rose into domes, the inner parts solidifying as granite, and the outer, more viscid portions having their constituents dragged into rough parallelism with the adjoining solid rocks and forming gneiss.

As the Huronian rocks south of Lake Superior and in New Brunswick are described by Van Hise and Dawson as presenting basal con-

glomerates resting unconformably on the Laurentian, it is suggested that in these cases the thickness of the sediments was not great enough to depress the Laurentian floor to the level of fusion or plasticity; or, that the Huronian, as recognized in these regions, is really younger and overlies the upturned edges of the rocks described as Huronian in the northern Archean.

Comments.— The above discussion is based on the most thorough field work yet done in this area, and the account probably marks an advance in the interpretation of the pre-Cambrian stratigraphy of the area northwest of Lake Superior, although the conclusions cannot yet be accepted as final. Some of the conclusions differ from those of other workers in this area, and such may be especially noted.

The Couchiching is believed to be entirely a sedimentary series, conformably below the Keewatin, and in eruptive contact with the Laurentian granite and gneiss below. Lawson regarded the Couchiching as sedimentary, but believed that there was an unconformity between it and the Keewatin, because of the great differences in the characters of the materials, the degree of crystallization, and the presence of basal conglomerates in places at the base of the Keewatin. Coleman has previously accepted these conclusions. Van Hise, accepting Lawson's conclusion as to the position of the Couchiching below the Keewatin, supposed the Couchiching to belong to the Basement Complex or Archean. However, recent personal work in the field has led him to the conclusion that the Couchiching of Rainy Lake is largely a sedimentary series, which is equivalent in age to the upper part of the series mapped by Lawson as Keewatin in the same area.

The insistence on the eruptive contact of all the rocks of the Laurentian with the Huronian and the explanation of the origin of the Laurentian may also be noted. Coleman believes that the gneisses and granites of the Fundamental Complex do not represent the earth's *erstarrungskruste*, but are portions of the earth's crust, of sedimentary or other origin, which have been buried deeply enough for hydrothermal fusion, and have afterwards been disinterred by long-continued denudation. After fusion of course such rocks would be really eruptive and of later age than the Huronian rocks above, even though originally they may have been older than them and formed the floor upon which the Huronian rocks were deposited. This is essentially the position of Lawson. Van Hise, on the other hand, believes that here the granites and gneisses heretofore included under the Laurentian of this

region may be separated into (1) a granite-gneiss basal complex, forming the basement upon which the Huronian was deposited, and perhaps representing a portion of the original crust of the earth or its downward continuation, and (2) later granite and gneiss intrusive in the Huronian, and therefore of Huronian or post-Huronian age. This discrimination has been uniformly made south of Lake Superior, in a number of cases in Canada, and in other parts of North America, and it is believed that it may also be made in this region of western Ontario. If this were done the rocks of the true fundamental complex in this area would occupy perhaps a very small area. Whether such a complex may be called Archean, as advocated by the United States geologists, or by some other name, is immaterial. If the term Laurentian be employed, it would need to be redefined to cover the narrower range of rocks, and because of its present wide application, including both the basal complex and later eruptives, some confusion might result. The term Archean has been carefully defined and consistently used by the United States geologists to represent the oldest group of rocks or basal complex, and in this narrow application has priority to any other term.

The portion of the granites and gneiss intrusive in the Huronian would be called simply Huronian or post-Huronian. If the true basal complex be altogether absent in this region, the granites and gneisses now called Laurentian are of Huronian or post-Huronian age, and are not to be correlated with rocks of the true basal complex of other areas.

Parks [1] describes the geology of the base and meridian lines in the Rainy River district, in an area extending from Lac Seul on the northwest and Lake Wabigoon on the southwest, to Sturgeon Lake and Mattawa Lake on the east. Laurentian and Huronian rocks occur in folds with a general northeast-southwest trend. The Huronian rocks occur in three main areas, the Sturgeon River area, the Lake Minnetakie area, and the Wabigoon Lake area. They consist of altered traps, hornblende-schists and other green schists, altered porphyrites, quartz porphyries, phyllites, and conglomerates. In general they resemble Lawson's Keewatin series to the south. The Laurentian consists of hornblende-syenite, hornblende-granite-gneiss, mica-syenite, biotite-granite-gneiss, and various granitic rocks. C. K. LEITH.

[1] Geology of base and meridian lines in the Rainy River district, by W. A. PARKS: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 161–183. With geological map.

Reviews

Report on the Building and Decorative Stones of Maryland. By George P. Merrill and Edward B. Mathews. Part II, Vol. II, Geol. Survey of Maryland.

The first 75 pages of the Building Stone Report of the Maryland Geological Survey are written by George P. Merrill, and comprise a discussion of the physical, chemical, and economic properties of building stones. The following 116 pages are written by Edward B. Mathews, and are an account of the character and distribution of Maryland building stone.

In the first part Merrill classifies the rocks of Maryland, which are available for constructive and ornamental purposes, into (1) granites and gneisses; (2) common limestones and dolomites; (3) the marbles (crystalline limestones and dolomites); (4) sandstones and conglomerates; and (5) the argyllites and slates. The three great classes of rocks, eruptive, clastic sedimentary, and metamorphic; the diversity of the geological resources of Maryland; the method of formation, present position, and the conditions under which the sedimentary and igneous rocks formed; and the way in which mountain-building forces have since modified them, are successively discussed.

The author explains how several grades, and often kinds, of sedimentary rocks may occur in a single quarry. The effect which the position of the strata, horizontal or tilted, has upon the cost of quarrying; the size and shape of the blocks resulting from jointing and bedding; the manner in which river erosion, weathering, and glaciers influence the accessibility of the stone in the quarry; and the misleading nature of dry seams and superficial induration, are clearly explained.

Following a discussion of the general distribution of Maryland building stones in reference to the physiographic regions of the state, Merrill considers the methods of quarrying and the more important kinds of machinery now employed. The important part which competition plays in the development of the stone industry has led to a

brief discussion of the quarrying industry of each of the Atlantic coast states. In this the author briefly describes the kinds of rocks quarried and reviews the character of the output and the facilities for successful development. It is concluded from these observations that the future of the quarrying industry of Maryland must depend not so much upon the kinds of materials as upon the ability to compete in prices.

After treating the subject of weathering in general, Merrill refers more particularly to the effects of alternating temperatures and the freezing of included water. The danger of laying stone on edge, on account of the freezing of water which may collect along the sedimentary planes, as well as the results of water freezing in the pores of the rock, are emphasized. In this connection the author concludes that "other things being equal, a stone possessing low absorptive power will be more durable . . . . than one that will absorb a large amount;" "granites and gneisses, possessing low ratios of absorption, and being made up so largely of silica and silicate minerals, are very little affected by freezing and solution;" and that "a ratio of absorption of more than 4 per cent. by weight (in sandstones) must be regarded as unfavorable."

In a discussion of the physical tests Merrill describes in an interesting manner the more important methods employed by different experimenters in performing the various durability and strength tests. In the discussion of the freezing and thawing tests the observation is made that "the results obtained on coarse and fine varieties of Portland sandstone suggest at least that water would freeze out of coarse stone, and therefore create less havoc than in those of finer grain." In the discussion of the specific gravity the conclusion is reached that "of two stones having the same mineral nature, the one having the highest specific gravity, that is, the greatest weight bulk for bulk, will be the least absorptive, and hence, as a rule, the most durable." The method suggested for determining the weight per cubic foot of stone is to multiply the weight of a cubic foot of water by the specific gravity of the stone. The method suggested for obtaining the absorptiveness of the rock is the one commonly employed, of soaking the sample in water for three or four days and determining the percentage gained in weight thereby.

In speaking of the crushing strength of stones, the author believes that to continue making these tests is unnecessary, except in "extreme cases."

Since the first of the century the quarrying industry of Maryland has received attention incidentally from many different students of geology. The various publications which have resulted from these studies are summarized by Mathews in the first pages of the second part of the report. Mathews considers the more important quarry areas under the heads of (1) granite and gneiss; (2) marbles, serpentines, and limestones; (3) quartzite and sandstones; and (4) slates and flags. This classification is somewhat different from that followed by Merrill in the first part of the report.

In the treatment of each area the author gives a brief historical sketch of the development of the industry, and a discussion of the rocks as they occur in the quarry. In some instances the microscopical and chemical analyses are given, and also the results of physical tests, including a determination of the crushing strength, ratio of absorption, specific gravity, and weight per cubic foot. The rock as it occurs in the quarries and natural exposures; the mineralogical composition and texture; and the colors of the granite, limestone, marble, serpentine, and sandstone, are well illustrated by cuts, photomicrographs, and colored lithographic plates.

The granites of Maryland are shown to be ordinarily schistose, and mainly of a gray color. The granite from one or two of the quarries is described as having a reddish or pinkish color, but possessing a porphyritic texture. In the case of the rock known as gneiss, occurring in the vicinity of Baltimore, the color and texture vary with the alternation of layers. In all cases the dimensions are controlled by jointing planes, which strike in various directions, owing to which the stone can often be used only for the smaller constructional purposes.

The marbles and limestones of Maryland are the most widely distributed of all the building stones, and occur in most of the formations from the Algonkian to the Triassic. The Cockeysville marble is exploited the most largely, and is probably the best known of Maryland limestones or marbles. The Potomac marble is a conglomerate with a striking color and texture, and is the only stone of this character used to any extent in the United States.

Serpentine has been quarried in several places, mainly for decorative purposes. Dry seams have seriously interfered with the successful development of this stone, and the quarries have been temporarily abandoned.

Sandstone is quarried extensively in only one locality, Seneca. The

best stone in the quarries is interstratified with beds of unsalable material, which naturally interfere with the economy of working.

Slate has been quarried in two different areas in Maryland, known as the Peach Bottom district and Ijamsville. The former district is the only one in which quarrying is now actively carried on. From this district a good quality of slate is obtained. The output has shown a slight decrease since 1894, when it reached its maximum importance.

E. R. BUCKLEY.

Fifteenth Annual Report of the State Geologist (New York) for the Year 1895, Vol. I. JAMES HALL, State Geologist, Albany, 1898.

THIS report, published in a ponderous volume of 738 pages with broad margins, large type and heavy paper, is particularly unwieldy, and would be far more convenient for the student were it issued in a size and form conformable with the preceding reports of the survey. It is particularly aggravating to the librarian to have a continuous series of reports which should be kept together upon his shelves vary so greatly in size. The 1894 report and those preceding it are convenient sized octavo volumes, while this 1895 report is a great book standing fourteen inches high, although the matter contained, page for page, is about equivalent to that in the earlier reports. The edition of the report, issued as a part of the regents' report of the New York State Museum, is printed upon thinner paper, and has the margins trimmed down so that it is a more convenient size, but even that is considerably larger than the preceding reports of the survey.

The criticism upon the style of publication, however, cannot be extended to the contents of the volume as each one of the papers communicated is a valuable addition to the literature of New York geology, and many of them are of more than local interest. Each of the papers will be briefly noticed, much of what follows being taken from the "Synopsis of Results" by the state geologist upon pages 11–26 of the report.

Two paleontologic papers, both by James Hall, (1) "A Discussion of Streptelasma and Allied Genera of Rugosa Corals," and (2) "The Paleozoic Hexactinellid Sponges Constituting the Family Dictyospongidæ," are announced in the synopsis of the report but do not appear. However, since this volume is marked Volume I on the title-

page, it is possible that another part containing these papers is contemplated.

1. *The Stratigraphic and Faunal Relations of the Oneonta Sandstones and Shales, the Ithaca and Portage Groups in Central New York.* By J. M. CLARKE. Pp. 27–81, plates I–VII and two maps. "This report presents a revision and summary of observations previously made by the same author with reference to the position of the Oneonta sandstones and their extent westward from the Chenango River, and adds thereto more recent data bearing upon the passage of the Ithaca fauna in the region of its highest development in Cortland and western Chenango counties into the typical fauna of the Portage group."

"The *Portage group* is a series of arenaceous deposits representing the geological time which elapsed from the close of the Hamilton period (including the Tully limestone and a portion of the Genesee slate when present) to the opening of the Chemung period. The typical and unmixed fauna of its westerly sections has little organic relation to the proper fauna of the Hamilton shales, the Chemung fauna succeeding, or the Ithaca faunas adjoining on the east. It is an exotic fauna, evidently derived from the west and making its first appearance in the Genundewah limestone of the Genesee slates. It is the *Naples fauna*."

"The fauna of the central and east-central sections is an indigenous fauna, and its organic composition stands in the closest relation to the fauna of the Hamilton group, but in its later manifestations assumes many characters of the Chemung fauna. In the Chenango Valley and eastward the upper portion of the deposits of this age is represented by the Oneonta group with a very sparse fauna and well-characterized strata. In Chenango county they replace the higher beds bearing the Ithaca fauna."

2. *The Classification and Distribution of the Hamilton and Chemung Series of Central and Eastern New York.* By C. S. PROSSER. Pp. 83–222, plates I–XIII and one map. The investigations described in this report were undertaken in order to trace the boundaries of the Oneonta group of sandstones and shales and to elucidate as far as possible the division line between the Hamilton group and the overlying strata. This latter is a perplexing problem because east of the Chenango River the Tully limestone and Genesee slate are wanting and the sandy shales of the Hamilton group pass upward into those of the Ithaca group with slight lithologic changes and with alterations of

the fauna so gradual as to be perceptible only upon very careful observation. It is shown that the more or less barren Sherburne sandstones separate the faunas of the Hamilton and Ithaca groups, and represents the beds which have been designated as Lower Portage in western New York. The correctness of this correlation is shown by the discovery of the typical Tully limestone species *Hypothyris venustula* = *H. cuboides* just below the Sherburne sandstone near Nobleville in Otsego county very much farther east than this species has been previously found.

The results of Prosser's investigation necessitate the changing of the upper boundary of the Hamilton formations from five to fifteen miles further south than the similar line on the geologic map recently published by the Geological Survey of New York.

3. *The Stratigraphic Position of the Portage Sandstones in the Naples Valley and the Adjoining Region.* By D. D. LUTHER. Pp. 223–236, plates I–II and one map. The purpose of the investigation described in this paper was to ascertain the dividing line between the Portage and the overlying Chemung group in western New York. The section of the Portage series in the Naples Valley is described in detail, and the Portage sandstone which marks the upper limits of the series is shown to lie at an elevation of 600 feet above the base of the series. With the data derived from the study of the Naples section the Portage sandstone is traced eastward to Seneca Lake and westward to Lake Erie.

4. *The Economic Geology of Onondaga County, New York.* By D. D. LUTHER. Pp. 237–303, plates I–XXI and one map. In this paper the rock formations of the county, from the Clinton group below to the Portage shales above, are discussed in their proper order of succession. While attention is given to the geologic character and distribution of each formation, the especial value of the report consists in its exhaustive treatment of the most important economic products of the county, viz., salt, soda-ash, gypsum, hydraulic cement and quarry stone.

5. *The Structural and Economic Geology of Erie County.* By I. P. BISHOP. Pp. 305–392, plates I–XVI, figures 1–6. This paper opens with a brief account of the topography of the region, after which the stratigraphic succession is discussed at considerable length. The formations present extend from the Salina group at the bottom to the Portage group at the top. The superficial deposits are discussed under

the head, "Quaternary Geology." The economic products of the county which are discussed are building stone, hydraulic cement rock, clays, sand, gravel and natural gas. In connection with the discussion of these products many valuable statistics are given and a considerable amount of space is devoted to the records of wells which have been sunk for natural gas in and about Buffalo.

6. *Geology of Orange County.* By H. RIES. Pp. 393–475, plates I–XLII, with one geological map. In this report the physiography and topography and the stratigraphic, structural and economic geology are ably discussed in detail. The formations present extend from the pre-Cambrian gneiss at the base of the section to the Chemung group at the summit. The economic products described are road materials, brick clays, limestone, lead ore, building stone, flagstone, and iron ores, besides the soils, mineral springs, water power and water supply.

7. *Report on the Crystalline Rocks of St. Lawrence County.* By C. H. SMYTH, JR. Pp. 477–497. The principal purpose of the investigation described in this paper was to determine the distribution of the crystalline limestones, and to collect data bearing upon the question of the origin of the gneisses and the relation existing between these rocks and the limestones.

8. *Report on the Geology of Clinton County.* By H. P. CUSHING. Pp. 499–573, plates I–V. This paper discusses the topography and general geology of the region, after which each township is treated separately. The rock series discussed are, (1) gneissic series; (2) limestone series; (3) gabbro series; (4) Paleozoic series, extending from the Potsdam sandstone to the Utica slate; (5) dike series; (6) pleistocene deposits.

9. *Preliminary Report on the Geology of Essex County.* By J. F. KEMP. Pp. 575–614, plates I–XII. This is a continuation of the report by the same author in the 1893 report, and the townships not previously described are taken up for special consideration and the areal geology of each is described so far as it has been determined. Special notice is taken of economic products, namely, of iron ores.

10. *Sections and Thickness of the Lower Silurian Formations on West Canada Creek and in the Mohawk Valley.* By C. S. PROSSER and E. R. CUMMINGS. Pp. 615–659, plates I–XII. The writers here consider the Ordovician rock sections exposed in the gorge of the West Canada Creek at Trenton Falls, at Newport and at Little Falls. These

sections have all been previously studied by other observers, some of them frequently, and not always with concordant results. In this paper, both measurements of thickness, and identification of species of fossils have been made with care, and while the conclusions are not in complete harmony with already expressed opinions, they doubtless afford a more precise knowledge of the formations considered.

11. *Report on the Talc Industry of St. Lawrence County.* By C. H. SMYTH, JR. Pp. 661–671.

12. *Physical Tests of the Devonian Shales of New York State to Determine their Value for the Manufacture of Clay Products.* By H. REIS. Pp. 673–698. This paper is introduced by a brief discussion of the general, chemical and physical properties of shales. This is followed by some notes upon the manufacture of paving brick and the requisite qualities of such brick. The remaining pages are devoted to a discussion of the extent of the New York shales with tests of samples from typical localities.

13. *The Discovery of Sessila Conularia.* By R. RUEDEMANN. Pp. 699–728, plates I–IV. This important paper is based upon the study of some obscure organisms found in the Utica slate at Dolgeville, N. Y. As a result of the study much light is thrown upon the nature and mode of development of this widespread but little understood organism, *Conularia*, in regard to whose taxonomic position there has been a widely diverse expression of opinion. *Conularia* has usually been referred to the Pteropods, but the results of the investigation recorded in this paper seem to indicate that it should be placed with the Cephalopods.

14. *Notes on Some Crustaceans from the Chemung Group of New York.* By J. M. CLARKE. Pp. 731–738. In this paper are discussed two crustaceans from the Chemung group, (1) *Pephricaris horripilata*, a peculiar, highly ornamented Phyllocarid crustacean, and (2) *Bronteus senescens*, one of the very few trilobites of this formation.

STUART WELLER.

Iron Making in Alabama. By W. B. PHILLIPS. Alabama Geol. Surv., Second Ed., 380 pp. 1898.

It is not often that a state survey finds it necessary to issue a second edition of any of its reports, and the fact that Dr. Phillip's well-known report now appears in new form is a well deserved compliment

to both the author and the enterprising Survey of Alabama. It is more than that; it is a very notable indication of the rapid progress which Alabama is making in iron making. An examination of the report shows this progress strikingly. Over a hundred pages of new matter have been added and chapters on Coal and Coal Washing, Concentration of Low-Grade Ores and Basic Steel and Basic Iron, indicate the lines of progress. The first edition of the report was intended for a general treatment from the point of view of raw materials. The new edition, by the addition of much valuable matter, has become as well almost a manual on iron making from low grade ores and is accordingly of much wider usefulness. In bringing together widely separated technical papers and adding to the material so much from the results of his own laboratory, Dr. Phillips has placed all interested in the subject in his debt. It is unfortunate that so good a report should be presented in such poor form. The paper, press work, and proof reading leave much to be desired. H. FOSTER BAIN.

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ERRATUM

On page 38, eleven lines from the top, instead of "*are frequently found one foot*," read "*are sometimes found one-half mile*."